MC0169

Please return to
ROSEMARY GLANVILLE
MARU: Environmental Design
Polytechnic of North London
Holloway Road, London N7 8DB

HOSPITAL TECHNICAL MEMORANDUM

ELECTRICAL SERVICES: SUPPLY AND DISTRIBUTION

7

MINISTRY OF HEALTH : LONDON : HER MAJESTY'S STATIONERY OFFICE
NOVEMBER 1963 PRICE 7s. 6d. NET.

MINISTRY OF HEALTH HOSPITAL TECHNICAL MEMORANDUM No. 7

Electrical Services: Supply and Distribution

CONTENTS

		Page No.
	List of Illustrations	1
I	Scope	2
IIA	Abbreviations used	2
IIB	Symbols used in diagrams	3
III	Compliance with regulations	3
IV	Stages in design	4
V	Procedures in design	4
VI	Design of installations for growth and change	5
VII	Distribution system	5
VIII	Estimating maximum demand	5
IX	Diversity factors	6
X	Standby electricity supply	7
XI	Power factor correction	7
XII	Choice of supply voltage	8
XIII	Choice of main distribution voltage	9
XIV	High Voltage distribution	9
XV	High Voltage switchgear	14
XVI	High Voltage cables	17
XVII	High Voltage transformers	20
XVIII	Medium Voltage distribution	21
XIX	External Medium Voltage distribution feeders	23
XX	Internal Medium Voltage distribution feeders	25
XXI	Medium Voltage switchboards	27
XXII	Earthing	30
XXIII	Record drawings	32
XXIV	Handing-over procedure	32
Appendix I	High Voltage sub-stations	32
Appendix II	Medium Voltage switchrooms	38
Appendix III	Service ducts	40
Appendix IV	Typical sizes and ratings for copper and aluminium busbars	42
Appendix V	Medium Voltage cable joints	42
Appendix VI	High Voltage cable joints	47
References		50
Index		52

List of illustrations

Figure 1. Symbols used in diagrams.

Figure 2. Capacitor sizes in kVAr for power factor correction.

Figure 3. Approximate cost comparison of high voltage and medium voltage feeders.

Figure 4. High voltage ring main with directional protection using graded time-lag relays.

Figure 5. High voltage radial distribution with medium voltage standby ring interconnector.

Figure 6. Typical arrangement of high voltage ring main using ring main units and fuse-switch protection for transformers.

Figure 7. Arrangement of high voltage ring main using ring main units with ring isolators and circuit breakers.

Figure 8. Two-transformer sub-station with busbar coupling and one remote transformer with interconnector.

Figure 9. High voltage ring main using differential current protection with back-up protection at main sub-station and overcurrent and earth fault protection for transformers.

Figure 10. Two-transformer sub-station with medium voltage busbar switching.

Figure 11. Safe short-circuit current and MVA values for 11 kV 3 core belted, paper insulated, lead sheathed and single wire armoured cables.

Figure 12. Approximate comparative cost of transformers (1962).

Figure 13. Typical medium voltage distribution.

Figure 14. Sub-distribution centre incorporated in rising main duct.

Figure 15. Typical sub-distribution centre incorporated in rising main duct.

Figure 16. Sub-station earthing.

Figure 17. Typical layout of a two-transformer sub-station as a separate building.

Figure 18. Typical layout of a two-transformer sub-station incorporated in a hospital building.

Figure 19. Typical example of a two-transformer sub-station with medium voltage switchroom only incorporated in a hospital building.

Figure 20. Small sub-station with outdoor transformer and high voltage ring main unit switchgear.

Figure 21. Typical medium voltage switchroom.

Figure 22. Typical ducts for services.

Figure 23. Dimensions for medium voltage straight through cable joints.

Figure 24. Concrete protection box suitable for straight through joints showing minimum dimensions and general arrangement.

Figure 25. Dimensions for medium voltage tee joints with concrete protection box.

Figure 26. Typical lead sleeve joint for 11 kV belted cable with concrete protection box.

Figure 27. Dimensions for high voltage 11 kV straight through cable joints.

Figure 28. Typical concrete protection box for 11 kV straight through joints showing minimum dimensions and general arrangement.

Figure 29. Methods of bonding wire armour across joints encased in non-metallic protection boxes.

I. Scope

1. This technical memorandum is intended to assist those engaged in the design of hospital electrical installations. It is applicable primarily to new hospitals and major developments but the principles will also apply when large alterations and extensions to existing electrical installations are planned.

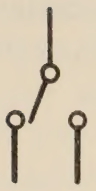
2. Guidance is given on the choice of supply and distribution voltages and equipment, together with examples of typical distribution systems, sub-stations and switchrooms.

IIA. Abbreviations used

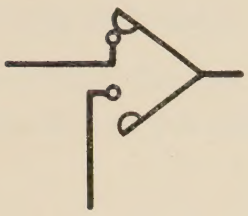
3.

B.E.B.S.	British Electricity Boards' Specification.
B.S.	British Standards issued by the British Standards Institution.
E.R.A.	Electrical Research Association.
H.R.C.	High rupturing capacity.
H.V.	High voltage (exceeding 650V).
I.D.M.T.	Inverse definite minimum time.
I.E.E. Regulations.	The Regulations for the Electrical Equipment of Buildings issued by the Institution of Electrical Engineers.
kVAr	Kilo-volt-ampere, reactive
M.I.M.S.	Mineral insulated, metal, sheathed.
M.P.F.E.	Maximum prospective fault energy, under symmetrical fault conditions i.e. a short circuit between all three phases.
M.V.	Medium voltage (voltages exceeding 250V but not exceeding 650V).
MVA Rating	The mega-volt-ampere rated fault energy handling capacity of switchgear, etc.
N.J.A.C.	National Joint Advisory Council of the electricity supply industry.
P.F.	Power factor.

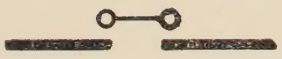
IIB. Symbols used in diagrams



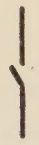
MANUALLY OPERATED CHANGE-OVER SWITCH.



CHANGE-OVER CONTACTOR.



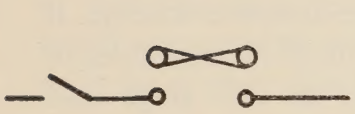
ISOLATOR USED AS BUS-SECTION SWITCH.



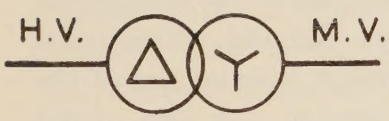
ISOLATOR.

FUSE-SWITCH OR SWITCHFUSE.

CIRCUIT BREAKER.



FUSE OPERATED OIL SWITCH AND ISOLATOR AS USED ON HIGH VOLTAGE RING-MAIN UNIT.



TRANSFORMER SHOWING PRIMARY AND SECONDARY WINDING ARRANGEMENTS.

A.C. GENERATOR.

REMOVABLE LINK.

Figure 1. Symbols used in diagrams.

III. Compliance with regulations

4. Installations should comply with the following regulations where appropriate.

1. Electricity Supply Regulations, 1937. (H.M.S.O.)
2. Electricity (Factories Act) Special Regulations 1908 and 1944 (H.M.S.O.).
3. Regulations for the Electrical Equipment of Buildings (Institution of Electrical Engineers).
4. Overhead line Regulations for securing the safety of the public (H.M.S.O. form EL.C 53).

IV. Stages in design

5. It is essential that the design of the electrical services should be progressively integrated in the design of the hospital as a whole as the relevant design data is worked out at each of the various stages of planning.

V. Procedures in design

6. At the first stage (assessment of need) it will be necessary to establish in broad terms the probable maximum electrical demand for the scheme. Data on this point is given in Section VIII.

7. Preliminary consultations should be held with the supply authority to obtain information on the availability and routing of supply mains, in order to assist in determining the most suitable situation for the intake, sub-stations, etc. The financial arrangements governing the provision of the supply and tariff charges should also be discussed. Under the provisions of the Electric Lighting (Clauses) Act, 1899, consumers can be required, if the supply authority so decides, to meet the cost of the supply lines which are required on their own property and for any supply lines in excess of 60 ft from an existing distrubition feeder.

8. At the next stage (when operational policies are being considered) decisions will be taken which will affect the general layout and primary needs of the electrical services. During the preparation of the development plan it will be necessary to determine the type of supply and distribution to be employed. The choice will be influenced by:

(i) The development plan itself, showing layout, size and type of buildings.

(ii) The site location relative to the supply authority's distribution system and the charges involved in providing the supply.

9. A supply from a h.v. network is desirable. This makes for better voltage regulation, improved earth fault protection and reduced interference from other users. Except in urban areas where there is an integrated m.v. supply, a h.v. transformer sub-station will usually be justified for hospitals of say 150 beds and upwards. It is preferable that a hospital sub-station should supply only the hospital's requirements, but where financial savings can be made without detriment to the hospital supply, limited feeding out to other users might be considered.

10. When preparing schedules of accommodation, further steps in the general design can be taken with the detail given in the schedules and information on the major items of equipment to be installed. Preliminary space details should be provided for transformer sub-stations, switchrooms, etc. But it should be borne in mind that the planning of the electrical services should be related to the conception of the complete scheme. If the work is to be built in phases, not all the schedules of accommodation will be available at this stage and reference to some of the data established in earlier stages will be necessary to complete the picture. This should ensure that the installation as a whole is designed to meet the estimated maximum demand, which must take account not only of the present scheme and of the need to allow for growth and change, but also of the fact that consumption will continue to increase in the future (see also Section VIII).

11. At the sketch plans stage, the requirements for transformer sub-stations, switchrooms and sub-distribution centres should be determined on the drawings as well as the requirements for distribution in both horizontal and vertical ducts.

12. These will be indicated by an examination of the most heavily loaded areas of the hospital and the determination of the 'centres of gravity' of the electric loads, which may differ considerably from the geographical centres of the complex of buildings. Some typical details are included in Appendices I, II and III.

13. At the working drawings stage, precise details of the builders' work, openings, etc., should be given to the architect for work to be carried out by the building contractor.

VI. Design of installations for growth and change

14. The Ministry's forthcoming Hospital Design Note on Industrialisation of Hospital Building will describe the general principles of dimensional co-ordination and will include a section dealing with the need for adaptability in hospital design—that is planning for growth and change to allow for changing medical and nursing techniques.

15. Provision for the possibility of limited internal adjustments and provision for external growth may be made, in terms of electrical services, by ensuring that distribution layouts are as far as possible related to the dimensional principles of the buildings; an extension technique should be used where growth is intended and adequate space in ducts, plant rooms etc. must be provided. Finally, it is important, in order to achieve successful cost planning, that the electrical sub-contract is tendered for at the same time as the main contract for the work.

VII. Distribution system

16. The distribution system should be flexibly designed to allow for the possibility of the load pattern changing. In general, greater flexibility will be obtained by the provision of sub-distribution centres having a reasonable amount of spare busbar capacity in positions to suit the load pattern, rather than by providing numerous separate sub-main circuits with limited spare capacity at each distribution board.

17. Whether to use ring or radial distribution will be influenced by a comparison of the economics of the two systems. Ring distribution normally provides greater flexibility and is particularly suitable for compact distribution systems incorporating several sub-distribution centres. Normally, however, it increases the prospective fault energy and special attention must be given to discrimination in the circuit protection in order to prevent widespread interruption of the supply under fault conditions. This is discussed further in subsequent paragraphs.

18. Reliability of equipment is of great importance with hospital installations and compliance with a British Standard should be specified where a relevant Standard exists. Switchgear, fuses, etc. should be standardised throughout the installation as far as possible, to assist maintenance and simplify the stocking of spares.

19. The installation should as far as possible be designed to spread the load over the twenty-four hour period, e.g., by taking advantage of reduced off-peak tariffs for loads such as space and water heating.

20. Unnecessary segregation of circuits can add considerably to installation costs and, apart from normal installation requirements, circuits should be kept separate only where necessary for reasons of safety or to minimise interference, e.g., where circuits are subjected to heavy transient loads such as x-ray apparatus and lifts.

VIII. Estimating maximum demand

21. Table 1 gives some data on the maximum demand of some typical existing hospitals, taken from electricity consumption records over a period of approximately 10 years. These show that maximum demand has increased at a fairly uniform rate of about 10% per annum.

TABLE 1

Typical electrical loads—existing hospitals

1	2	3	4	5	6	7
Type of hospital	No. of beds	Lowest max. demand kW/bed	Highest max. demand kW/bed	Average max. demand kW/bed	Average % increase over approx. 10 years	No. of hospitals considered
General	Up to 250	0·51	1·03	0·8	78	9
	251 to 400	0·3	1·25	0·75	99	9
	401 to 800	0·33	1·1	0·6	98·5	9
Teaching hospitals	358 to 805	0·45	1·6	1·0	123	6
Psychiatric hospitals	982 to 2470	0·14	0·29	0·23	109	5
Maternity hospitals	88 to 201	0·57	0·79	0·65	100	3

Note

The figures in col. 2 for Teaching, Maternity and Psychiatric hospitals relate respectively to the smallest and largest of the hospitals considered.

22. During the period covered by these records there has been a general upgrading of lighting standards in hospitals and a considerable increase in the use of electricity in the preparation and distribution of food. Data available suggests however that electricity consumption in hospitals in this country is still lower than in some other countries and the indications are that both maximum demand and overall consumption will continue to increase in future. Among the factors which are likely to lead to greater use of electricity are planning in depth which requires higher standards of lighting, mechanical ventilation and air-conditioning and an increase in the use of automation and electro-mechanical aids, particularly in departments such as laboratories, laundries and kitchens.

23. Table 2 gives suggested values for the planned capacity of main distribution feeders and busbars for new schemes where the heating will be mainly by non-electrical means.

TABLE 2

Suggested electrical loads-new hospitals

Type of hospital	Number of beds	Suggested maximum demand kW/bed
District General	Up to 500	3·0
,,	Over 500	2·5
Teaching	Up to 500	3·5
,,	Over 500	3·25
Psychiatric	Up to 500	1·3
,,	Over 500	1·25

24. The values given are intended only as a general guide to assist in planning the capacity of the intake and main distribution equipment of a new scheme. The figures assume that all the departments needed for that type of hospital (including staff accommodation) will be provided.

25. It will be necessary to include further capacity for any non-typical loads such as any group or centralised departments which will serve other hospitals.

IX. Diversity factors

26. It is not possible to indicate firm diversity factors for the main distribution circuits in hospitals. The maximum demand loading of these will vary considerably between hospitals because of differing working arrangements.

27. The following values are given as a general guide:

Lighting, wards	50%
Lighting, offices, laboratories	80%
Lighting, operating theatres	90%

Lighting, other departments	75%
General purpose socket-outlets	2—5%
Kitchen Equipment (heating and power)	100% of largest load +60% of remainder
Laundries (power)	100% of largest load +70% of remainder
Laboratories (equipment and power)	100% of largest load +80% of next largest load + 50% of remainder.
Boilerhouse (power)	100% of largest load + 75% of next largest load + 40% of remainder.
Operating suites (heating and power)	100% of largest load +80% of remainder.
Fixed Space heating	75%
X-ray circuits	See para. 133.

X. Standby electricity supply

28. Medical and surgical procedures and mechanical means of communication are becoming increasingly dependent upon electrical apparatus, and it will normally be necessary to provide, by prime movers, a standby electricity supply which is completely independent of the normal supply, in order to maintain essential services in district general, teaching, and certain other types of hospitals.

29. Figures 5 and 13 indicate typical switching arrangements for standby electric supply but are not intended to indicate the extent to which emergency standby facilities are necessary.

30. With larger installations the emergency supply installation should be divided into separate circuits according to the degree of priority and the disposition of the essential equipment. The changeover should be arranged in a sequence according to priority, and suitable time intervals allowed in the changeover timing to reduce the starting load.

31. In addition to maintaining essential services in the event of a total supply failure, it is desirable that the emergency supply arrangements can be used to safeguard against a distribution feeder failure or a failure involving one of the h.v. units to enable part of the non-essential load to be supplied from the standby generator. Typical switching arrangements for this are indicated in figures 5 and 13. This arrangement will also enable a major h.v. unit to be isolated for servicing purposes.

32. It is important that interlocks are provided to prevent any load being connected to the standby supply before the normal mains isolator is in the open circuit position and to prevent the normal supply being re-instated before the standby supply is isolated.

33. Emergency electricity supplies will be dealt with in greater detail in a separate Ministry publication.

XI. Power factor correction

34. Typical overall power factors for hospital loads range between 0·85 and 0·95. With an increase in the use of mechanisation, there is a tendency towards lower power factors, but in general, special measures for power factor correction have not been considered necessary.

35. The economics of power factor correction are largely influenced by the type of tariff in use. Where there is a power factor penalty clause, correction would normally be justified if there is a possiblity of the power factor falling below the penalty limit.

36. Where a maximum demand charge is specified in kVA, power factor correction may enable a saving to be made where there is a higher than usual inductive load. To establish whether or not correction is economically desirable and to determine the economic limit of correction, it will be necessary to estimate the uncorrected power factor and equate the cost of the reactive components (kVAr) in terms of the maximum demand kVA charge against the annual cost of the corrective capacitors. Assuming an economic life of 15 years for the capacitors, the annual capital charge will be approximately 10% of the total cost of the capacitor installation.

37. Since much of the inductive load will occur only during part of each twenty-four hour period, e.g. during daytime, it will normally be necessary so to arrange the capacitor installation that it is switched with the inductive load. This will eliminate the possibility of a leading power factor during lightly loaded periods and prolong the useful life of the capacitors.

38. In general, however, it will be more economical to provide a few large capacitors rather than a larger number of small capacitors (for example one for each motor).

39. Figure 2 indicates the appropriate capacitor rating (kVAr) required for power factor correction to specific values up to 0 ·99.

The following formula will enable the most economical power factor to be determined:

$$\text{P.F.} = \sqrt{1 - \left(\frac{\text{Annual cost of capacitor installation in £'s per kVAr}}{\text{Maximum demand charge in £'s per kVA per annum}} \right)^2}$$

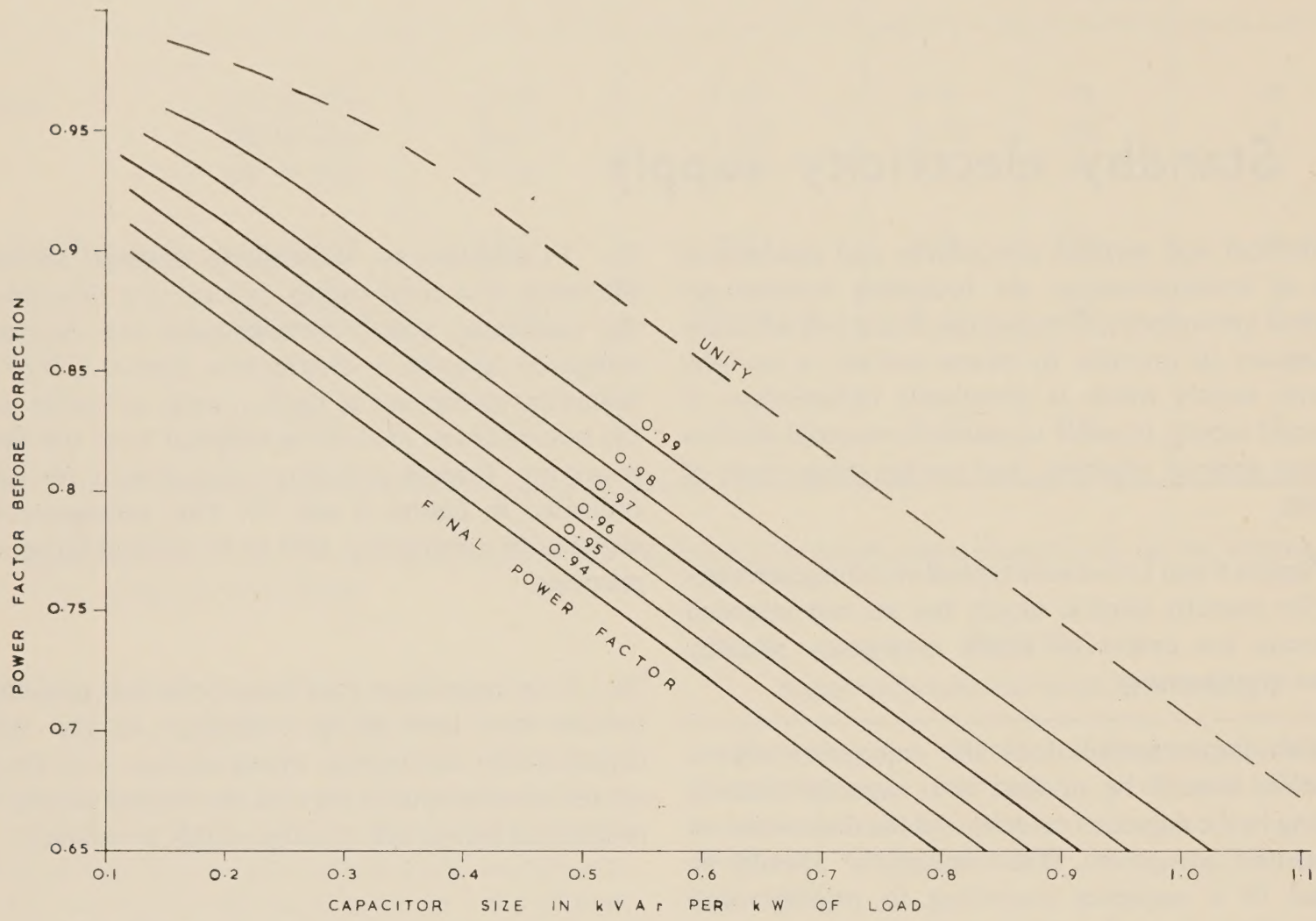


Figure 2. Capacitor sizes in kVAr for power factor correction.

XII. Choice of supply voltage

40. The choice of supply voltage will be determined by the supply facilities which are available, the prospective load and the extent of the hospital distribution system.

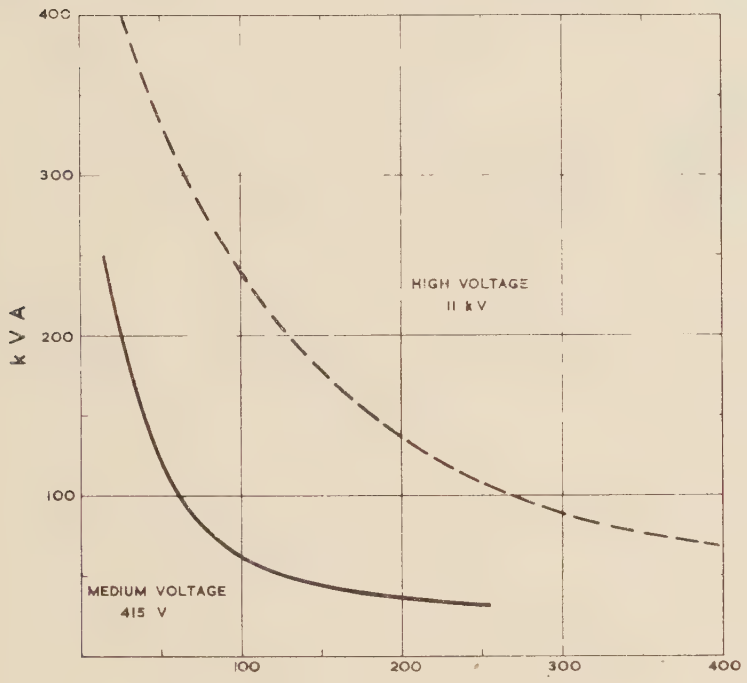
41. A supply from a h.v. network will provide the best voltage control and will usually minimise interference from other users. Where suitable supply facilities are available a h.v. supply will normally be justified for medium size and larger hospitals. The usefulness of a duplicate h.v. feeder will depend upon the supply distribution arrangements. A second feeder from the same supply network can safeguard against fairly local distribution failures: but this limited safeguard will probably be justified only for larger hospitals.

42. Exception to the advantages associated with a h.v. supply may occur in densely populated areas (for example the London area) where there is an integrated medium voltage network. This type of supply is potentially more reliable than a supply from a h.v. network, particularly where a second supply can be arranged from a different section of the network.

XIII. Choice of main distribution voltage

43. Depending upon the distance between the various departments of a large hospital it may be economical to employ h.v. distribution between the intake and sub-distribution centres. The choice of distribution voltage will depend upon economic considerations, taking into account the capital cost of installations and energy losses of the alternative systems. Figure 3 is intended as a rough guide to assist in determining the economics of h.v. or m.v. distribution. The comparison is based on the related capital and installation costs with associated iron and copper losses for a single spur feeder. The costing of medium voltage mains is based on a maximum voltage drop of 3% (allowable where a transformer with tap changing facilities is provided) whilst still enabling the voltage at at remote outlets to be within 1 volt +2% of the nominal voltage (as is necessary to comply with No. 204 of the I.E.E. Regulations).

44. The preferred voltage for h.v. distribution (B.S.77) is 11 kV and this voltage should be used whenever possible where h.v. distribution is economically justified.



1. The curves indicate the approximate cost demarcation between h.v. and m.v. feeders at 11 kV and 415 V respectively for a given load and length of distribution feeder.
2. Where the plotted length and kVA loading falls on the left hand side of the curve a m.v. feeder will be more economical. Plotted points on the right hand side indicates that a h.v. feeder would be the more economical.
3. The full curve line is based on the assumption that the transforming capacity and the number of transformers is unaltered, one transformer being installed remote from the intake.
4. The dotted curve is based on the assumption that the total transforming capacity is unaltered but that an additional transformer, circuit breaker and feeder will be required.
5. The cost comparison includes:—
   (a) Annual capital cost of switchgear, cables, and where appropriate transformers, based on a useful life of 30 years.
   (b) Where appropriate, an annual capital cost for the transformer chamber.
   (c) Annual cost of cable losses and transformer losses (where appropriate), calculated at 1.5d. per unit, allowing a load factor of 60% and based on the assumption that the most economic size of m.v. cable is used, with a voltage drop not exceeding 3%.
   (d) Annual maintenance cost of switchgear, cables and transformers where appropriate.

Figure 3. Approximate cost comparison of high voltage and medium voltage feeders.

XIV. High Voltage distribution

General

45. Where h.v. distribution is employed the aim should be to cover as much of the distribution as is practicable with h.v. cables and keep m.v. cables as short as possible. The system should be as simple as possible consistent with safety. H.V. switchgear and protection equipment is expensive and each unit is a possible source of failure; therefore only essential protective and switching units should be provided.

46. Where h.v. switchgear is provided by the supply authority, it should normally be unnecessary for the equipment to be duplicated as part of the hospital installation, since it is usually possible to have an arrangement with the supply authority whereby their switchgear may be operated in an emergency by hospital personnel. In some instances h.v. switchgear is provided on a shared basis.

47. The maximum prospective fault energy (m.p.f.e.) at the main h.v. isolators will depend on the arrangements of the supply authority's distribution network and should be ascertained from the Area Board. High voltage distribution which forms part of the hospital installation should be arranged to limit the m.p.f.e. as far as is convenient and practicable, by, for example, limiting the size of transformers and providing inter-

locks on busbar couplers to prevent paralleling of supply feeders.

48. Advice on the calculation of short circuit fault currents is given in Appendix J of B.S.936 and Appendix C of B.S.116.

Ring circuits.

49. With ring distribution schemes there is the possibility of a single fault causing a widespread interruption of supply unless steps are taken to restrict the disconnection to the faulty section. This can be achieved by using h.v. circuit breakers fitted with directional and time discriminating controls. A typical circuit is shown in figure 4. Because of the relatively high cost of h.v. switchgear such a distribution scheme would cost at least 60% more than a radial distribution (figure 5).

50. Simplified ring circuits (figure 6 and 7) with circuit protection only at the transformers and isolating switches for the ring, would show a considerable financial saving, but a fault on one leg of the ring cable would cause a complete loss of supply in the arrangement shown in figure 6 and can cause the loss of supply on some other section with the arrangement shown in figure 7, until the faulty section could be isolated. Such systems may be acceptable where an automatic stand-by alternator supply is available for essential loads.

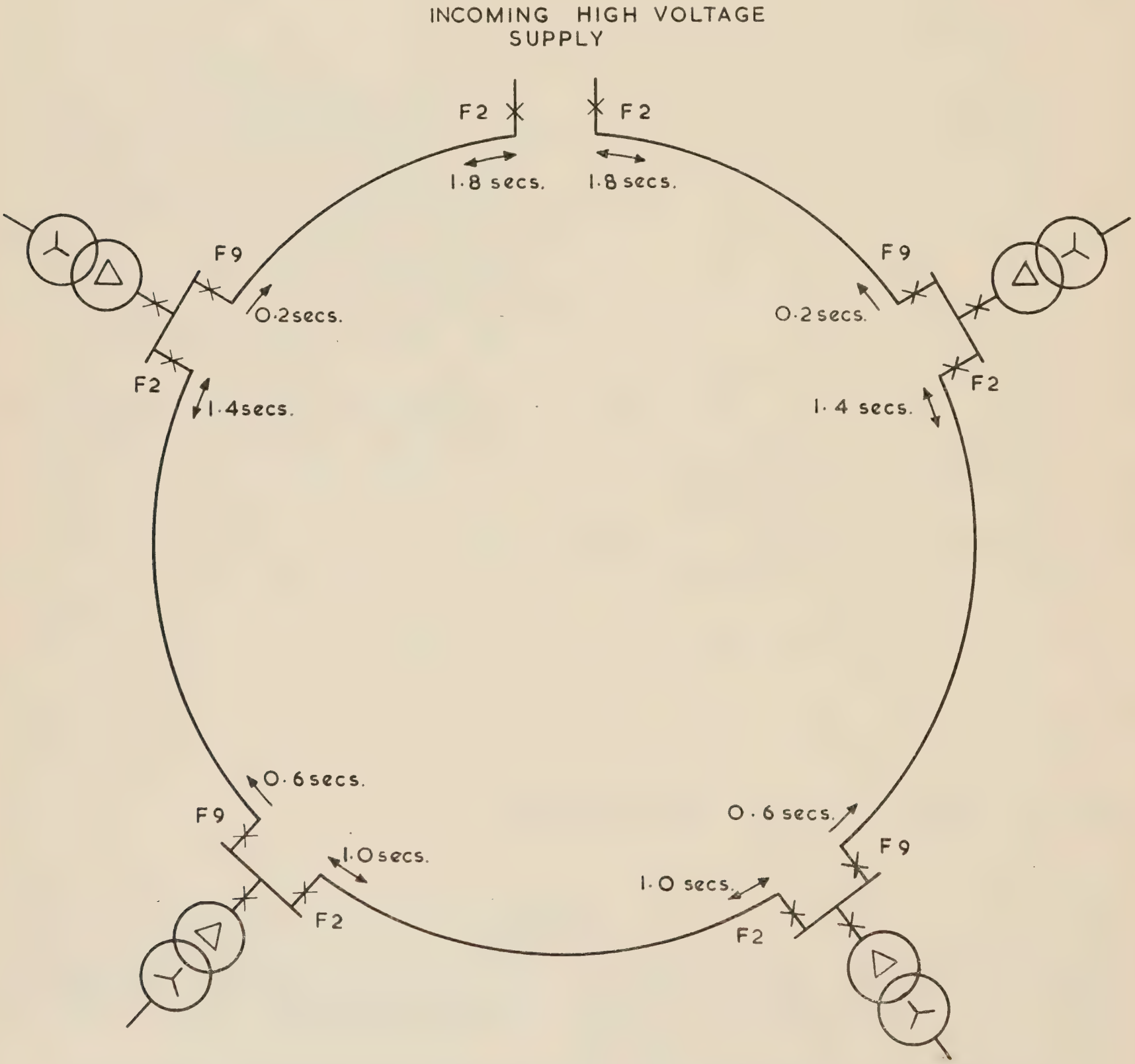
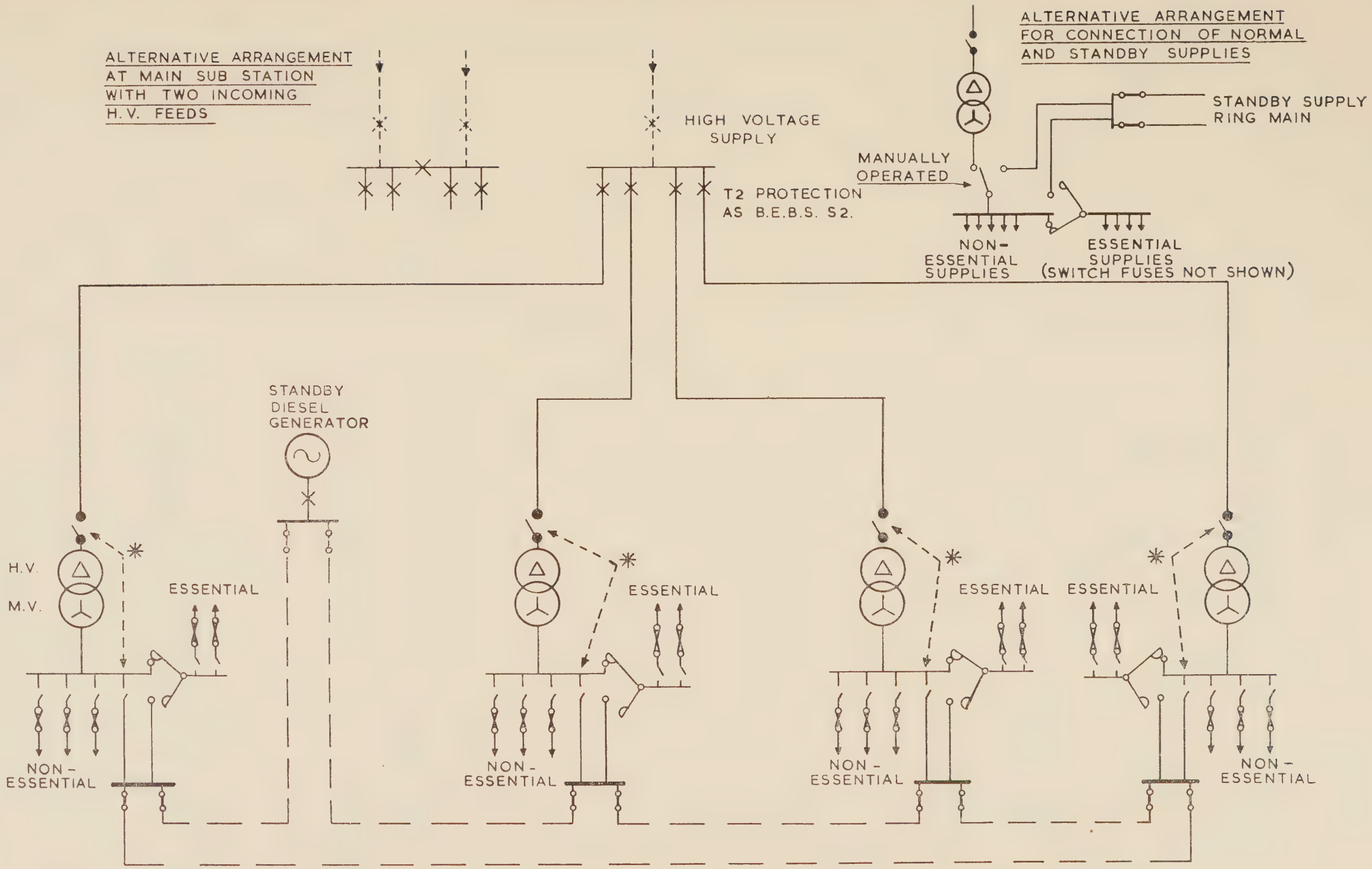


Figure 4. High voltage ring main with directional protection using graded time-lag relays.



* THE STANDBY SUPPLY SHOULD ONLY BE CONNECTED TO THE NON-ESSENTIAL SECTION OF THE SWITCHBOARD WHEN THE NORMAL SUPPLY IS SHUT DOWN FOR MAINTENANCE OR REPAIRS.
TRANSFORMER H.V. ISOLATOR ON NORMAL SUPPLY & M.V. ISOLATOR ON STANDBY SUPPLY TO BE KEY INTERLOCKED TO PREVENT PARALLELING OF THE TWO SUPPLIES.

Figure 5. High voltage radial distribution with medium voltage standby ring interconnector.

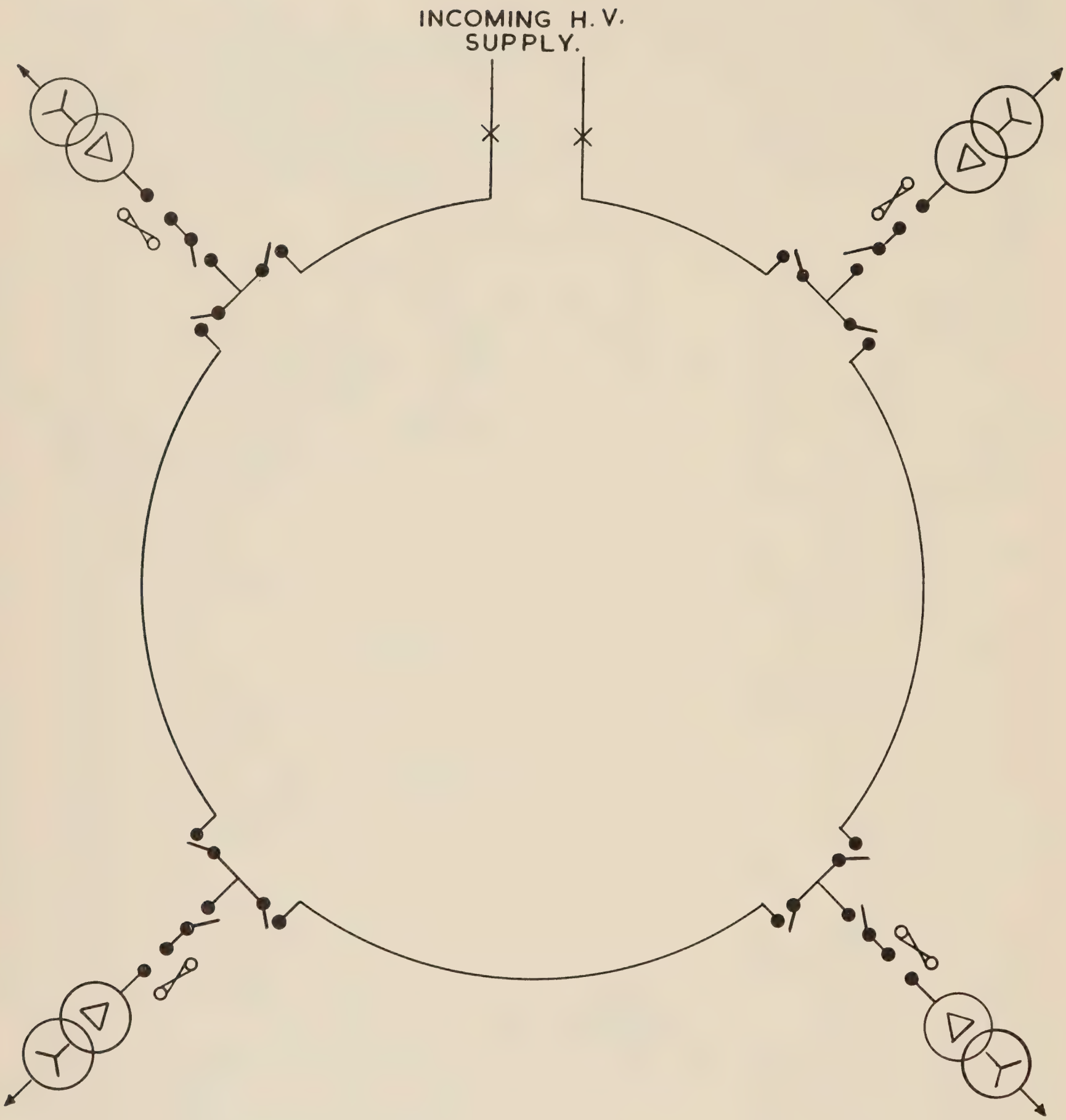


Figure 6. Typical arrangement of high voltage ring main using ring main units and fuse-switch protection for transformers.

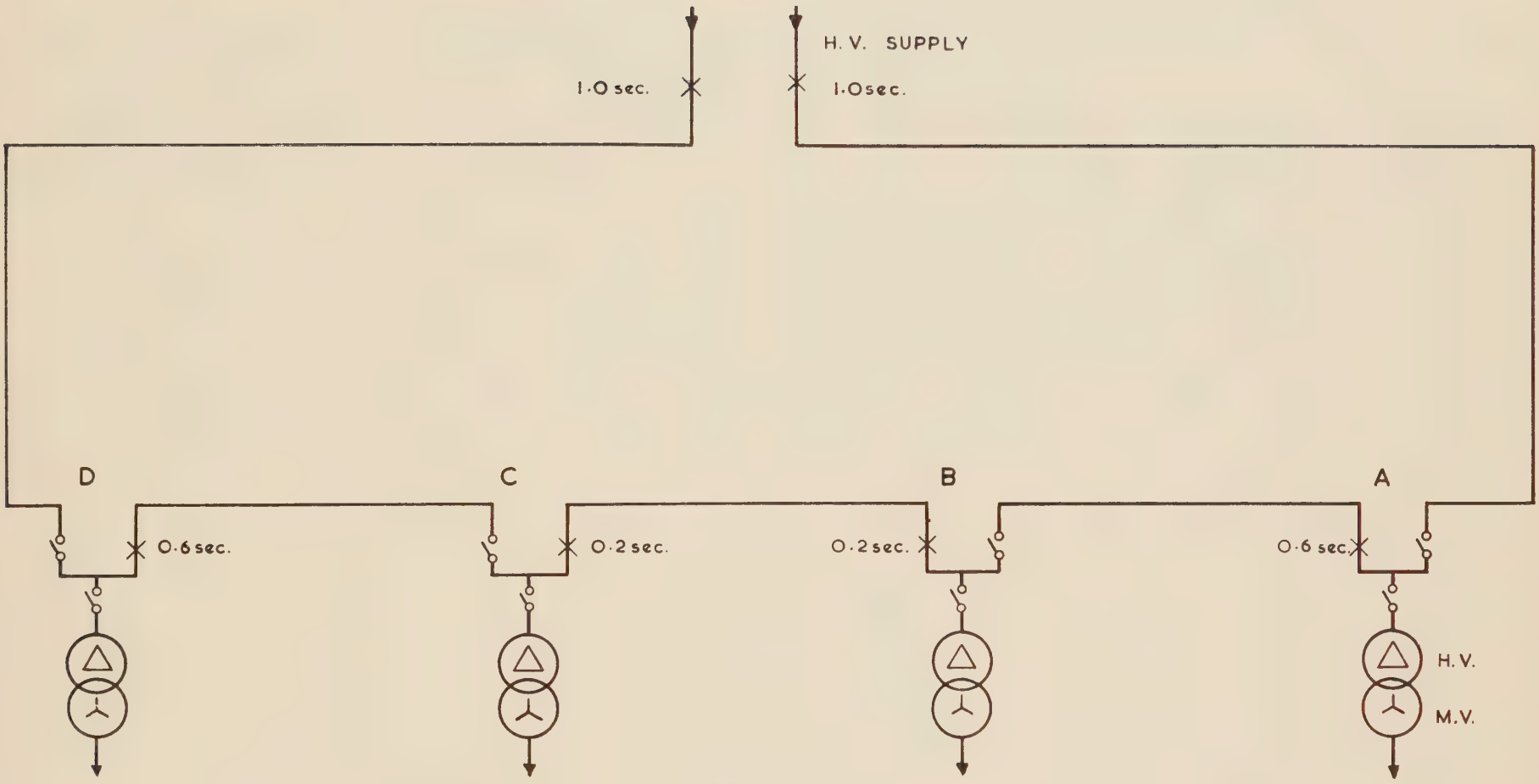


Figure 7. Arrangement of high voltage ring main using main units with ring isolators and circuit breakers.

Radial distribution

51. An alternative to a ring distribution is the use of radial h.v. feeders with m.v. inter-connector to safeguard against a failure on the h.v. side. Figure 8 shows a typical circuit arrangement.

Internal distribution

52. H.V. distribution will not normally be justified within buildings, except possibly in very tall blocks.

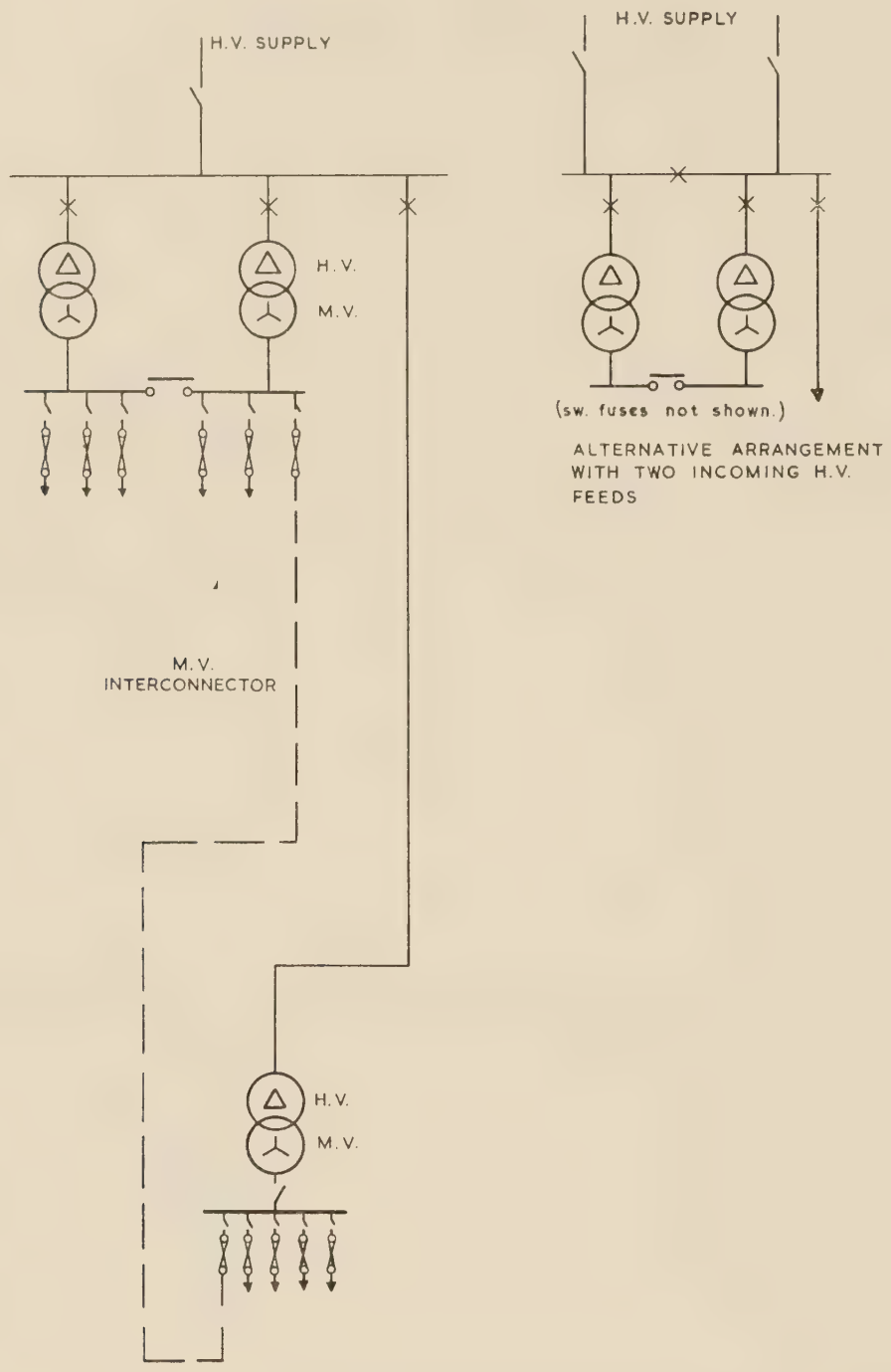


Figure 8. Two-transformer sub-station with busbar coupling and one remote transformer with interconnector.

XV. High Voltage switchgear

General

53. H.V. switchgear will normally be of the oil break type with air insulated or compound filled busbar and current transformer chambers. With some compound filled units the current transformers are oil immersed. Air or compound insulated units are suitable for indoor installation, but for outdoor installation compound filled types should be specified.

54. It is important that the maximum breaking capacity of switchgear should exceed the m.p.f.e., of the supply system, (which should be verified with the supply authority) and a certificate of type test should be obtained from the switchgear manufacturer.

55. The standard MVA ratings for 11 kV switchgear are 150 and 250 MVA. The appropriate current rating is 400 amperes.

56. The British Electricity Boards have a specification for standard distribution switchgear, B.E.B.S.-S.2, with addendum, which covers oil circuit breakers and oil switch equipment having fault energy ratings of 150 MVA at 6·6 kV and 11 kV, and 250 MVA at 11 kV.

57. The specification is based on relevant British Standards, in particular B.S.116 (Oil Circuit Breakers) and B.S. 2631 (Oil Switches). The aim is standardisation and variety reduction and thereby lowering costs.

58. The standard circuit-breaker is suitable for transformer, feeder or busbar section circuits. Alternative arrangements of protection and closing mechanism are allowed for to suit users' requirements.

59. Oil circuit breakers and switches conforming to B.E.B.S.-S.2 and with the appropriate protective arrangements will be suitable for most hospital applications; the following paragraphs are based on the assumption that they will be employed.

H.V. circuit breakers.

60. A well designed circuit breaker with appropriate current transformers, relay and tripping coils will satisfy all basic requirements for circuit protection.

61. Earth faults on cables will normally be of sufficient magnitude to operate the overcurrent protection. This may not always be the case, however, and it is usually considered advisable to provide for earth fault protection in addition to the overcurrent protection.

62. The simplest form of protection utilises direct acting trip coils which operate from current transformers and require no special d.c. energising supply. This type of protection is suitable for circuits which do not require accurate time discrimination. Where this is required an inverse definite minimum time (i.d.m.t.) relay will be necessary. For ring circuits employing time graded protection, some relays will be required to be of a directional type and incorporate a voltage reference winding.

63. As an alternative to the use of time discriminating protection with i.d.m.t. relays, a biased differential (circulating current type) protection system can be used with ring or long radial feeders, and has the advantage of rapid operation and disconnection of the faulty feeder without loss of supply to other parts of the distribution system. This method of protection employs matched current transformers at each end of the feeder with pilot cable inter-connections and a relay which is balanced when the current entering and leaving the feeder is of the same value. Although the relays operate rapidly in the event of a feeder fault, they will not be operated by through fault currents and overcurrent back-up protection will be necessary at the supply end of ring or radial feeders.

64. Biased differential protection systems eliminate the need for time-graded protection and thereby shorten the time that feeder cables will be subjected to fault currents. Table III illustrates that a reduction in operating time of the protective equipment may enable a smaller cable size to be used and the saving effected in this way can more than offset the extra cost of this type of protection, including the cost of the pilot cables. A ring circuit employing biased differential current protection is shown in figure 9.

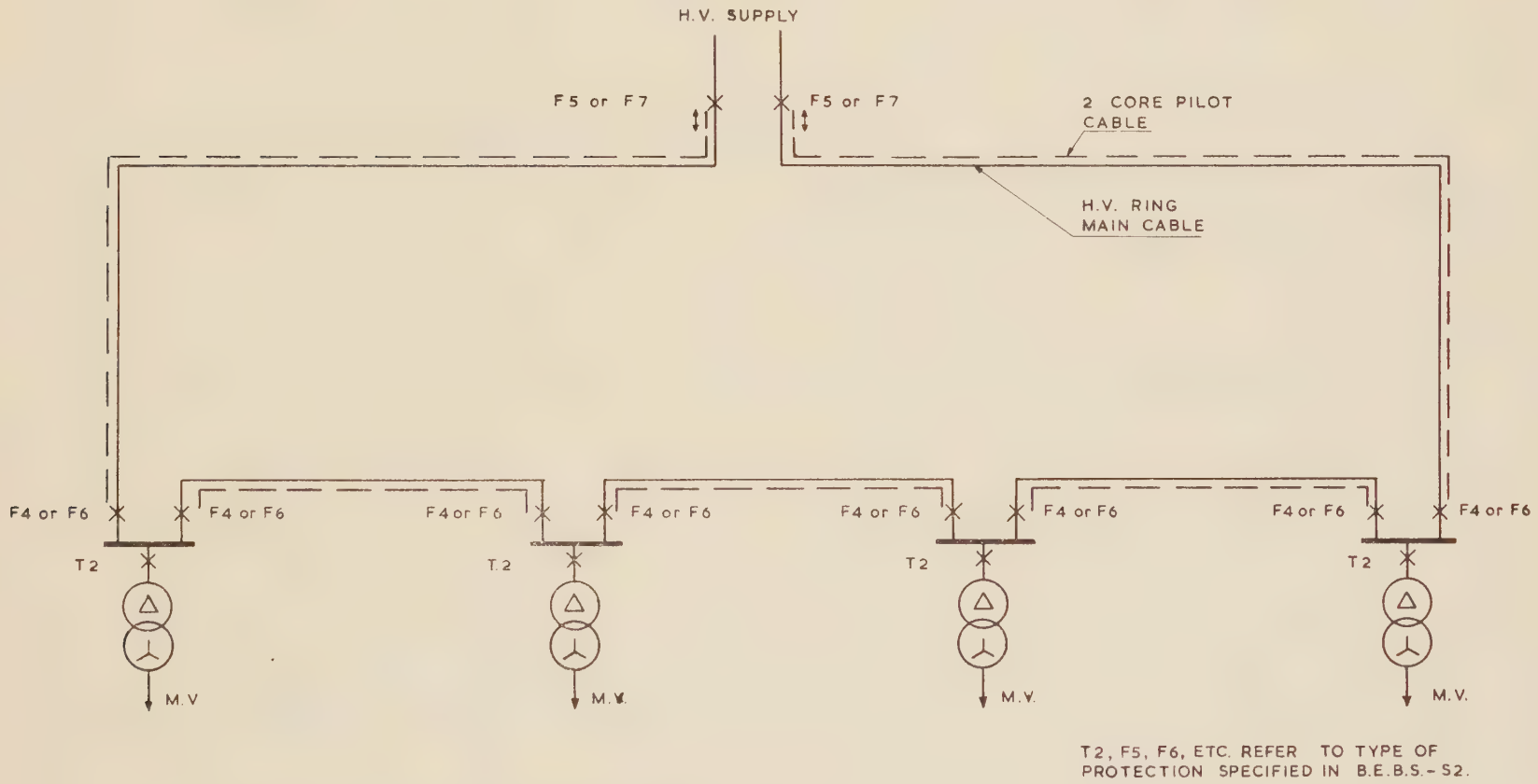


Figure 9. High voltage ring main using differential current protection with back-up protection at main sub-station and overcurrent and earth fault protection for transformers.

65. Various alternative protective arrangements are allowed for in B.E.B.S.—S.2. Those which are most likely to be applicable to hospital applications are as follows:

Transformer circuits

66. *Type T.*1 Overcurrent and earth fault protection by means of current transformer operated trip coil with time fuses. This system requires no special d.c. supply, is suitable for simple distribution systems where accurate time discrimination between different sections is not required, and will normally give satisfactory discrimination with circuits protected with h.r.c. fuses.

67. *Type T.*2. Overcurrent and earth fault protection by means of non-directional relays. This system requires a special d.c. supply to energise the trip coil circuit and is suitable for transformer circuits where accurate time and current discrimination is required between different parts of the distribution network, e.g. with a radial distribution system as shown in figure 5.

Feeder circuits

68. *Type F.*2 (form A—3 current transformers). Overcurrent and earth fault protection by means of non-directional relay. Suitable for ring and radial circuits where accurate time discrimination is required (figures 4 and 7).

69. *Types F.*4 *and F.*6 (form B—4 current transformers). Alternative system using biased differential protection suitable for ring and radial feeders. Figure 9 shows a typical ring distribution using this form of protection.

70. *Types F.*5 *and F.*7 (form C—6 current transformers). Alternative systems using biased differential protection with back-up protection. These are suitable for supply ends of ring and radial feeders where back-up protection is required to safeguard against the possibility of through fault currents (figure 9).

71. *Type F.*9 (form A—3 current transformers). Overcurrent and earth fault protection by means of directional type relay. Suitable for time graded ring circuits (figure 4).

Bus-section circuits

72. *Type B.*1. Non-automatic busbar coupler (figures 8 and 10).

Operating mechanisms

73. Manual, spring assisted, spring operated power closing, compressed air and solenoid type closing mechanisms are available.

74. The B.E.B.S.—S.2 specification includes two types of operating mechanisms:

(*a*) Spring operated manual closing.

(*b*) Spring operated power closing where the closing mechanism is operated by a previously hand-charged spring.

75. Where considered necessary an electrically operated release can be arranged and sited outside the fire risk area.

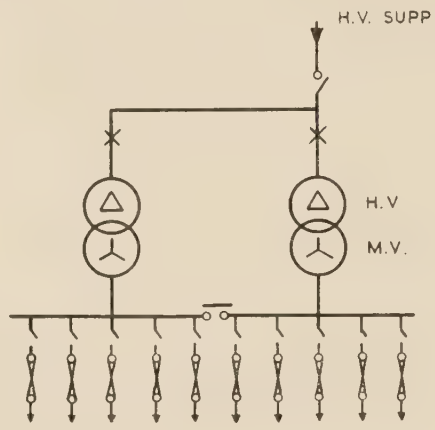
76. With inexperienced operators there is a possibility of slow closing speeds with manual closing mechanisms and this could cause severe damage to cables and breaker.

77. The spring operated power-closing mechanism will be suitable for most hospital applications. In extreme circumstances where prospective fault currents in excess of 250 MVA are possible, solenoid type operation should be specified.

78. Solenoids require a d.c. supply of approximately 6 kW. from a source independent of the mains, obtained for example from a diesel alternator and selenium type rectifiers or from a battery. B.S.162 states that voltages below 110 should not be used for this purpose. The provision of a special battery supply for solenoid operation would not normally be justified where a stand-by alternator supply is available.

Trip coil supply

79. A d.c. supply (normally 30 V) is required to energise the trip coil circuits, and an alkaline type battery is normally used for this purpose. In determining the battery voltage, allowance should be made for the voltage drop in the wiring to ensure that the coils operate at their rated voltage. Charging facilities should include an automatic low charging rate with manually controlled quick charging facilities.



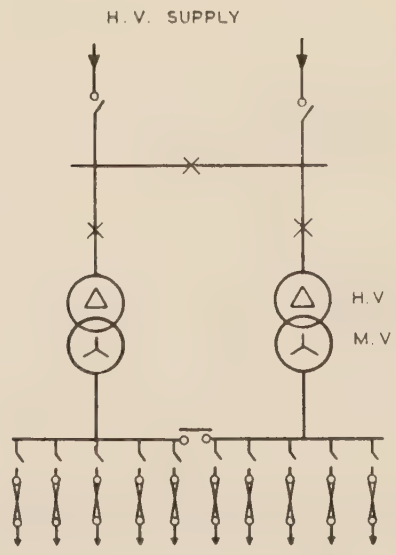


Figure 10. Two-transformer sub-station with medium voltage busbar switching.

80. The capacity of the battery will depend on the wattage consumption of the trip coils and the number of units to be supplied. Normally a battery within the range 10—25 ampere-hours would be suitable.

81. The battery should be housed in a fire-resisting (e.g. steel) enclosure and located outside the immediate fire risk area of the switchgear served by the battery. Wiring between the battery and the switchgear should have good fire resisting properties (e.g. m.i.m.s. cables) and should be installed well away from h.t. and main m.v. feeders.

Current transformers

82. Current transformers for use with protective equipment should comply with B.S.2046.

83. The ratios specified in B.E.B.S.—S.2 would normally be used. Alternative ratios 300/5A or 400/5A are available for oil circuit breakers for feeder protection. The 300/5A is suitable for working currents up to 350A and would therefore be suitable for most hospital applications.

Interlocks, safety shutters and labelling

84. Mechanical interlocks, safety shutter devices and labelling should be provided as specified in B.E.B.S.—S.2.

H.V. oil switches

85. Oil switches are considerably cheaper than oil circuit breakers and can be used instead of oil circuit breakers on ring circuits where time graded discrimination protection is not required. (figures 6 and 7).

86. B.E.B.S.—S.2 includes two types of oil switches each having a rated short circuit making capacity and short time rating equivalent to 250 MVA at 11 kV both in the "on" and "earth" positions.

87. The switches incorporate cable earthing facilities but cannot be fully isolated from both the feeder and busbars for servicing purposes. On ring circuits, therefore, they should only be used with a circuit breaker or other facilities to enable the switches to be isolated for servicing purposes.

88. Type O.S.2 is intended for use with an oil circuit breaker whereby two O.S.2 oil switches and one F.2 oil circuit breaker form a ring-main unit as shown in figure 7.

H.V. oil switch fuses

89. Oil switch-fuses are about two-thirds the cost of a comparable oil circuit breaker. They are normally equipped with h.r.c. fuses complying with B.S.2692. Their chief advantage is rapid operation, but they are not suitable for use in circuits where time discrimination is required. They are suitable for the protection of branch or radial feeders or for ring circuits where time discrimination is not required (figure 6).

XVI. High Voltage cables

90. The choice of cable to be used will be influenced by load requirements, prospective fault energy, length of run and method of installation.

91. Paper insulated lead sheathed cables complying with B.S.480 are suitable for most hospital applications. Varnished cambric insulated cables permit higher working temperatures but are more expensive and their use will normally be justified only where high ambient temperature conditions are likely.

92. P.V.C. insulated cables are not suitable for potentials exceeding 3 3kV.

93. The current ratings of h.v. cables should be in accordance with the tables given in E.R.A. report F.T/183, using the appropriate rating factor where the standard laying depth and temperature conditions are not complied with.

94. Belted paper insulated cables (having an additional outer layer of insulation) are cheaper than screened type (having a metallic screen surrounding each core) and have been found to be generally satisfactory for potentials up to 11 kV. Above this voltage the deteriorating effect of the electrostatic field has greater significance and screened cables are preferable.

95. H.V. cables should be capable of passing without suffering serious damage, the maximum prospective fault energy for the maximum period of time needed for the fault to be cleared. The thermal effect under fault conditions increases as the square of the time and this is an important factor where time discriminating protection is employed. The requirement for cables to handle the prospective fault current without serious damage may involve the use of larger cable sizes than would be required for the estimated current carrying requirements.

96. Because of the greater resistance to bursting under fault current conditions, belted cables are particularly suitable for smaller feeders where the operating time of protective equipment is short (e.g. up to 0·5 sec.). The additional strength resulting from the belted insulation is less effective, with time delays in excess of this value.

97. Table 3 and figure 11 give the recommended minimum cable sizes for various prospective short circuit currents and delay times.

TABLE 3

Recommended minimum cable sizes for various prospective fault MVA values and delay times for 11 kV. 3 core, paper insulated, belted, lead sheathed, single wire armoured, cables.

Fault MVA	Cable sizes in square inches for fault duration in seconds						
	0·2 sec.	0·3 sec.	0·5 sec.	1 sec.	1·5 sec.	2 sec.	3 sec.
25	0·0225	0·0225	0·0225	0·0225	0·0225	0·04	0·04
50	0·0225	0·0225	0·04	0·04	0·06	0·06	0·06
75	0·04	0·04	0·04	0·06	0·1	0·1	0·1
100	0·04	0·04	0·06	0·1	0·1	0·1	0·15
150	0·06	0·06	0·1	0·15	0·15	0·15	0·2
200	0·1	0·1	0·1	0·15	0·2	0·2	0·25
250	0·1	0·1	0·15	0·2	0·25	0·25	0·3

The above table and figure 11 are based on recommendations contained in ERA report F/T 195 and are related to a maximum conductor temperature of 160° C.

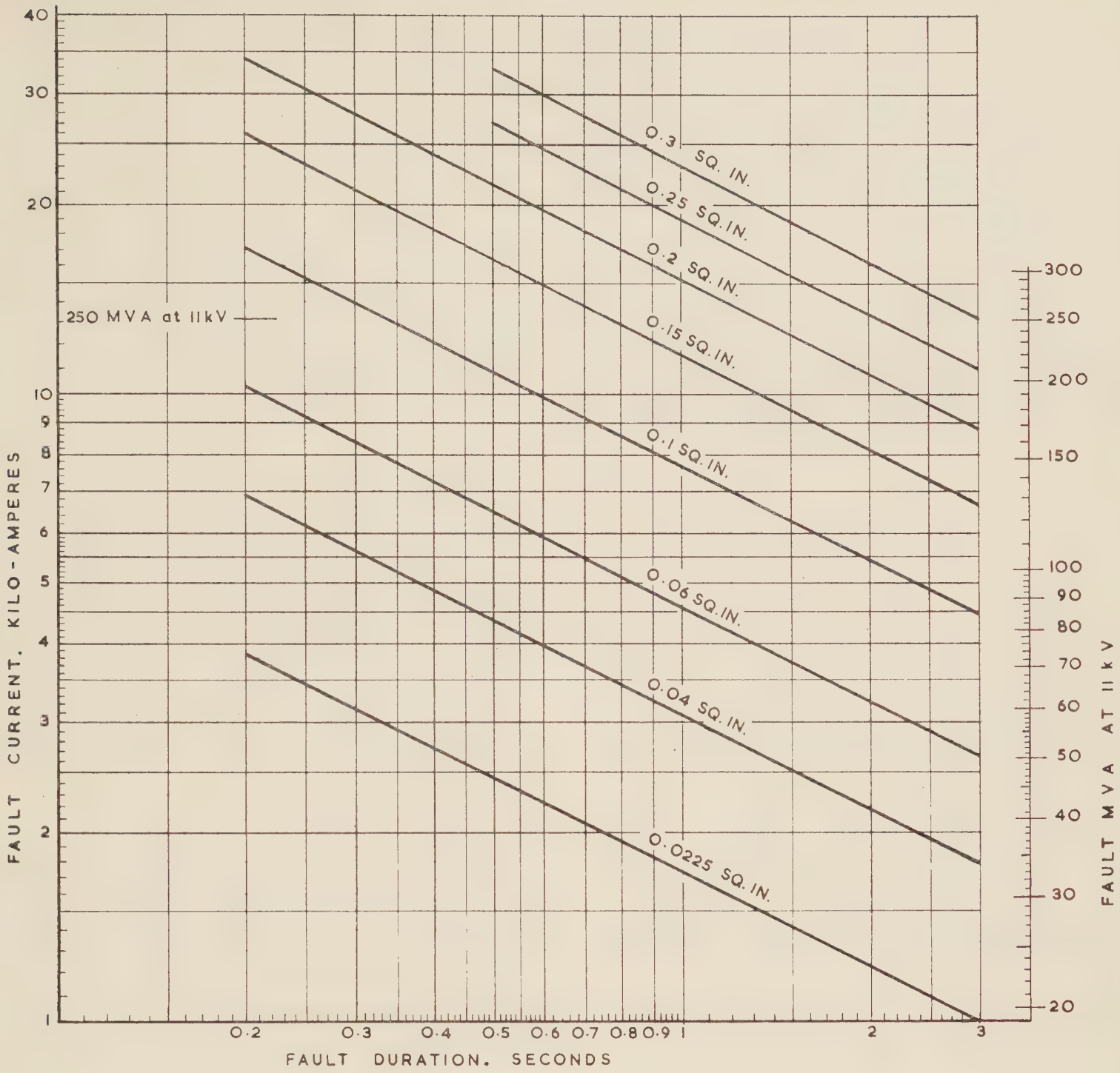


Figure 11. Safe short-circuit current and MVA values for 11 kV 3 core belted paper insulated lead sheathed and single wire armoured cables.

98. H.V. Cables should be joint-free as far as practicable. Where joints are necessary they should be made in accordance with the Code of Practice on High Voltage Joints, Electricity Council, Engineering Recommendation C 34.

99. For short runs in conduits or covered ducts (e.g. in sub-stations) armoured cables will not normally be required. For longer indoor runs involving bends, cables having single wire armouring left bright should be used to reduce the possibility of damage to insulation and sheath during installation.

100. Cables for vertical or steep gradient installation should be of a non-draining type and satisfy the test specified in B.S.480 in this respect.

101. For external runs single wire armoured and served cables are usually preferred. Where cables are liable to be subjected to excessive stresses double wire armouring should be specified.

XVII. High Voltage transformers

Type of transformer

102. Figure 12 shows the relative cost per kVA of the three types of h.v. transformer which are commonly used. The cost of dry type transformers includes a metal enclosure and it will be seen that for a given capacity they are approximately double the cost of oil cooled transformers, and that synthetic liquid cooled types are approximately mid-way between.

103. In considering the economics of the three types it should be noted that because of the lower fire risk with dry and synthetic liquid cooled types, capital saving will usually be possible by omitting special fire precautionary measures, including increased fire resisting separation and special fire extinguishing equipment.

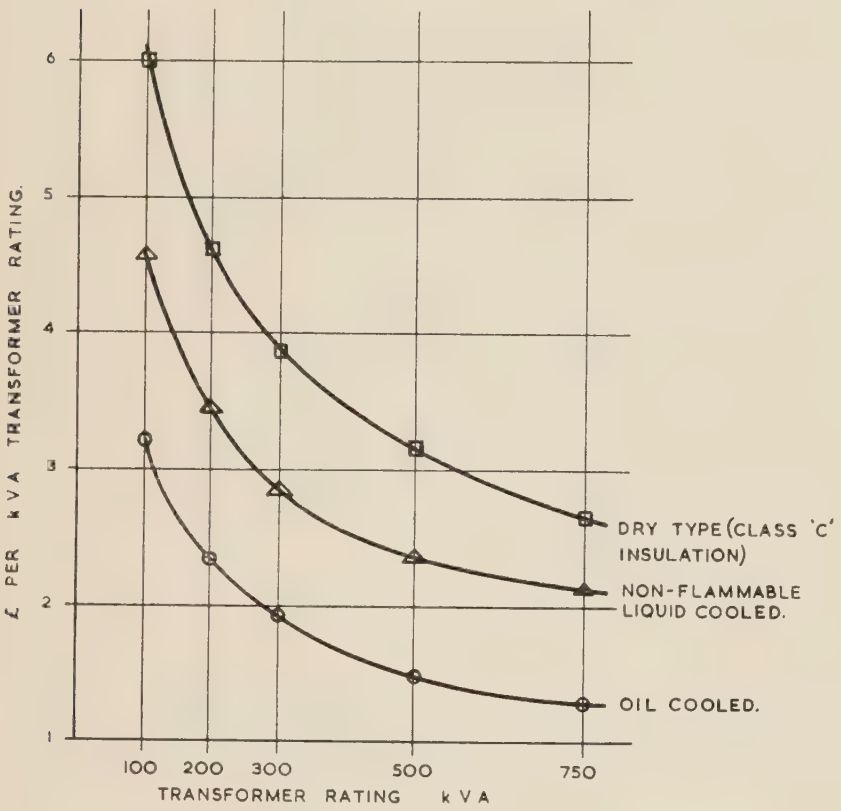


Figure 12. Approximate comparative cost of transformers (1962).

Number of transformers

104. The number of transformers required will depend on the load and the extent of the distribution. It is advisable that a minimum of two transformers should be provided and that emergency switching facilities should be included to enable a supply to be maintained to each section of the installation in the event of a failure involving a transformer or h.v. feeder.

105. With a compact hospital, two or more large transformer units installed in a centrally sited sub-station will normally provide the most economical arrangement. On larger dispersed hospital sites, three, four or even five transformers of varying size may provide the most economical distribution. The aim should be to cover as much distribution as is practicable with h.v. cables.

106. Figures 4—7 and 9 show typical distribution circuits.

107. With the cyclic load pattern normally experienced in hospitals, and taking into consideration capital cost, depreciation, copper and iron losses, it is economic to overload transformers up to 30%.

Size of transformers

108. Figure 12 shows that on a unit cost per unit kVA basis, the cost of transformers varies inversely as the capacity increases to 500 kVA and then tends to become more directly proportional. Although large transformers are cheaper per kVA and show a saving on the number of switches required, the use of larger units will usually mean longer m.v. distribution and will allow less flexibility than smaller units.

109. For most hospital applications there is no advantage in using transformers having capacities larger than 500 kVA. It is therefore desirable to limit the capacity to this size in order to restrict the m.p.f.e. on the m.v. installation and also reduce the extent of interruption of supply in the event of a failure involving one of the transformers or h.v. units. Where a large compact hospital requires centralised transformer capacity exceeding 1000 kVA it may be economical to employ transformers having capacities up to 750 kVA. Single transformers larger than this are not recommended for hospitals.

Oil-immersed transformers

110. Oil-immersed naturally cooled transformers and their associated fittings made to the British Electricity Boards' specification (B.E.B.S.—T.1) are suitable for most hospital applications. The specification is based on B.S.171 type 'ON'. The standard sizes for 11 kV 3-phase transformers are 100, 200, 300, 500 and 750 kVA with off-circuit primary tap changing facilities to allow $\pm 2\frac{1}{2}\%$ and $\pm 5\%$ variation of the primary voltage on all sizes. The specified winding connection for 3-phase transformers is delta-star to vector group 4, Dy.11 of B.S.171. The percentage impedance is 4·75 at 75 °C.

111. Cores constructed of cold reduced, grain oriented steel considerably reduce the iron losses, weight and size of the transformer and are therefore preferable to those of hot rolled steel. The iron loss requirements of B.E.B.S.—T1 should be complied with at 85% level flux density (13,000 lines per sq. cm.).

112. Oil conservators and gas and oil actuated relays (Buchholtz) are not normally considered necessary for the sizes of transformer within the size range recommended for hospital application (up to 500 kVA).

113. The standard fittings for sub-station type transformers in B.E.B.S.—T1 should be provided.

114. Where transformers will be situated outdoors or in main sub-stations close to the main h.v. switch room, it will normally be more economical to use oil cooled types.

115. Oil-immersed transformers should not normally be installed above the ground floor. The construction of transformer chambers and fire protection facilities are dealt with in Appendix I.

Dry-type transformers

116. Dry type air cooled transformers should comply with B.S.171 and have Class H or Class C (B.S.2757) type insulation.

117. They should be provided with a rating plate, terminal marking plate, lifting lugs and frame earth terminal. The transformers should be housed in cubicles of incombustible construction with safety interlocks on access doors arranged to trip the h.v. supply in the event of the door being opened whilst transformers are " live ".

118. Dry transformers may be preferred for smaller distribution sub-stations which are incorporated in the main hospital buildings where fire risk is an important factor. They tend to be noisy in operation and special attention should be given to the possibility of nuisance from this cause in selecting the site of sub-stations which will employ dry transformers.

Synthetic-liquid cooled transformers

119. Experience with synthetic liquid cooled transformers is very limited and there is no nationally accepted standard specification for the cooling liquids. This type of transformer appears to have no significant economic advantage over the alternative types and until there is more information about its ageing properties it would be advisable to defer installation of this type of transformer in hospitals.

Packaged transformer sub-stations

120. Packaged sub-stations are available in which a dry type h.v. transformer is incorporated in a composite unit with the m.v. switchboard. Such units are of compact design and enable the construction of a special transformer chamber to be eliminated. They do not require special fire protection and oil retaining facilities as do oil-immersed type transformers, and these savings may offset the higher capital cost of these units.

121. On the other hand packaged sub-stations provide little flexibility for future additions to meet increased demands and their use for hospitals will normally be confined to local sub-distribution centres.

Outdoor sub-stations

122. Outdoor sub-stations will enable a saving in capital cost to be made by eliminating the transformer chamber and special fire protection installation. They also provide improved cooling during the periods of heavy load which normally occur during winter months. Against this the maintenance costs including painting and oil sampling will be higher, particularly in or near industrial areas. Taking a long term view it is doubtful whether outdoor sub-stations will show any significant advantage in these areas. They may be considered suitable in clean air localities where a suitable site near main hospital buildings is available.

123. Transformers for outdoor use should be of the oil-cooled type and incorporate silica-gel breathers.

XVIII. Medium Voltage distribution

General

124. The distribution should be designed so that the voltage drop is within the specified limits depending on the source of supply, and so that the cables are suitably protected against the thermal effect of, and electro-mechanical stresses resulting from, excessive currents due to overloading or fault conditions.

125. Switchgear, busbars, etc. should be rated to withstand the m.p.f.e. of the system. Where the supply is obtained from a h.v. transformer having a capacity of 500 kVA the m.p.f.e. of the system will be well within the limits of switchgear having a 25 MVA rating.

126. Except in special circumstances as, for example, with X-ray and motor circuits, the maximum voltage drop at the remote points on the m.v. installation should not exceed 1 volt plus 2 per cent of the nominal voltage and the m.v. distribution should be designed to achieve this. The voltage drop can be readily calculated using the current rating tables of the I.E.E. Regulations, taking into account the appropriate rating factor where the ambient temperature conditions differ from the standard value of 30 °C allowed for in the I.E.E. Regulations (e.g. where cables are to be installed in ducts or voids containing heating services or laid direct in the ground).

127. The type of distribution used will depend on the layout of the hospital and load requirements. Maintenance of supply is particularly important in hospitals and, where economically practicable, inter-connections or ring circuits should be used to enable the supply to be maintained in the event of a fault involving a major supply component. A line diagram of a typical distribution scheme is given in figure 13.

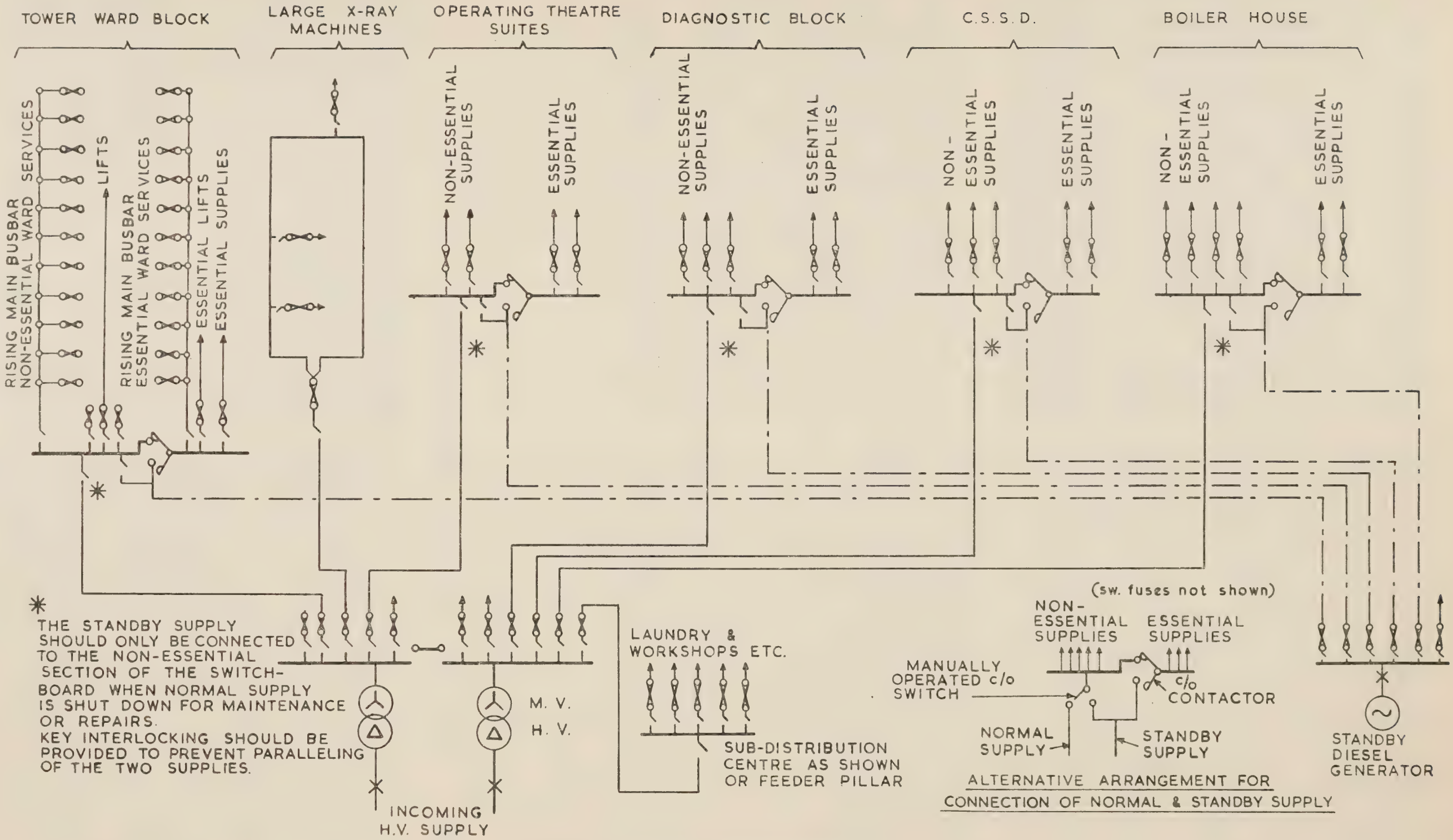


Figure 13. Typical medium voltage distribution.

Ring circuits

128. Ring circuits are particularly suitable where several distribution centres are fairly near together. With ring distribution, however, it is important that there is ample excess current discrimination between the sub-distribution circuits and the ring in order to reduce the possibility of through fault currents operating the ring protection and causing a major disconnection from the supply.

129. H.R.C. fuses should preferably be used for the sub-distribution circuits off the ring. Where h.r.c. fuses are used to protect the ring it is necessary to ensure that the total operating time of the minor fuse is less than the pre-arcing time of the major fuse. It is desirable to consult the fuse manufacturer for guidance on this point. As a general rule a 2:1 ratio will ensure discrimination with class Q h.r.c. fuses.

X-ray circuits

130. The special feature of x-ray circuits is the transient nature of the loads, a feature which can cause interference with other parts of the installation. To reduce this effect circuits supplying permanently installed x-ray equipment should be taken off separate sub-main feeders. Though comparatively heavy currents are used, the duration of the peak load rarely exceeds 1 second. There is therefore no problem of excess temperature rise, but it is important that the circuit wiring should be capable of carrying the maximum load without undue voltage drop. A maximum permissible voltage drop is usually specified by the makers of x-ray apparatus and the sizes of the circuit conductors should be chosen to satisfy these requirements. A typical value is 5% voltage drop at the rated load.

131. Because of the transient and intermittent loading of x-ray circuits considerable diversity factors can be allowed in determining the sizes of circuit wiring where several machines are to be supplied. A diversity factor can also be allowed in determining the rating of distribution switchgear supplying x-ray circuits because the switchgear is never likely to be required to make or break the circuit under peak load conditions.

132. The use of ring circuits will (as compared with spur type distribution) usually achieve a considerable saving in copper and also assist in reducing voltage drop where several x-ray machines have to be supplied.

133. Suggested diversity factors:

two machines: none

three machines: 100% largest load plus 50% other loads;

more than three machines: 100% largest load plus 40% other loads.

X-ray supply circuit wiring usually consists of fairly heavy conductors which have to be taken to wall mounted switchgear. M.I.M.S. cables are particularly suitable for these circuits in minimising chasing and reducing installation costs.

Lift circuits

134. Because of the fluctuating nature of the loads upon lift motor circuits, they should be kept separate as far as is practicable, to limit interference with other circuits.

XIX. External Medium Voltage distribution feeders

General

135. For external distribution either in conduits or ducts or laid directly in the ground, the following types of cables are available:

(*a*) paper insulated, copper conductors lead or lead alloy sheathed, armoured and served;	1,100 V. grade (B.S.480)
(*b*) paper insulated, aluminium conductors (complying with B.S.2791) lead or lead alloy sheathed, armoured and served;	1,100 V. grade (B.S.480)
(*c*) paper insulated, aluminium conductors (complying with B.S.2791) aluminium sheathed and served;	1,100 V. grade (BS 480 Pt.2)
(*d*) P.V.C. insulated, copper conductors, single wire armoured with p.v.c. serving (B.S.3346);	250/440 V. grade up to 0·04 sq. in. and 660/1,100 V. grade up to 0·5 sq. in.

Paper insulated cables

136. For a given current carrying capacity, paper insulated cables are the least expensive, but the special jointing necessary with this type of insulation increases installation costs. For feeders having few joints paper insulated cables will normally be the cheapest form of distribution and will, therefore, be suitable for most hospital applications.

Aluminium conductors

137. Paper insulated cables having aluminium conductors show a saving in cost compared with copper

conductors, depending on size. The cost difference is related to the market prices of copper and aluminium. At the present time (1963) the difference is small with the smaller sizes, but rises to about 20 per cent for the larger cables.

Lead sheaths

138. Lead or lead alloy sheaths should comply with B.S.801 which allows for the use of lead or three different lead alloys, "B", "D" and "E". Alloy "B" is a moderately hard alloy having better resistance to vibration and should be specified where this property is necessary. "D" is a hard alloy but lacks ductility, which makes it difficult to install. Its use is normally restricted to locations where severe vibration is likely. For general purposes, alloy "E" is used for unarmoured cables and lead for armoured cables.

Aluminium sheaths

139. Aluminium sheathed cables laid underground should have a suitable serving, but need not normally be armoured. Unless served, aluminium sheathed cables should not be installed in contact with walls or floors.

Joints

140. In general, tee joints in underground cables are not recommended. A possible exception is where several small units e.g. staff houses, are supplied from a common feeder. Where tee joints are used the current rating of the branch feeders should not be less than that of the fuse or the current setting of the circuit breaker protecting the supply feeder.

141. Information on m.v. and h.v. cable jointing is given in appendices V and VI.

Armouring

142. Wire armouring has better earthing properties than steel tape armouring, particularly at joints and terminations, and for this reason is to be preferred.

143. Single wire armouring is suitable for most external applications and double wire armouring would only be justified where cables are liable to be subjected to heavy stress, e.g. where subsidence may be expected.

Serving

144. Where paper insulated cables are installed in conduits or laid directly in the ground, they should have a compounded jute yarn, hessian or similar serving. Because of the highly flammable nature of this type of serving it should not be used on cables which are installed in ducts, walkways, voids etc., and the serving should be removed from underground cables where they enter buildings.

145. P.V.C. serving is available at an additional cost of approximately 25% on small sizes of cable (0·0225 sq. in.) and 10% on larger sizes (0·5 sq. in.) and, having regard to the extra cost, p.v.c. serving would only be justified in special circumstances e.g., where corrosion may be expected on internal cables.

P.V.C. insulated cables

146. P.V.C. insulated cables are more expensive than paper insulated cables but the absence of a metal sheath eliminates plumbing and simplifies installation. P.V.C. insulation, however, is much more prone to heat damage than paper insulation, and it is important that the circuit protection should prevent overloading which can permanently damage the insulation.

147. It is obviously desirable to standardise the type of circuit protection used for all sub-main circuits. Where, as is usual, class Q type fuses (fusing factor 1·75) are standardised, the use of a higher grade fuse (class P., fusing factor 1·25) for p.v.c. insulated cables should be avoided because of the possibility of the wrong type of fuse being substituted. In such circumstances the p.v.c. insulated cables should be derated to allow for the use of class Q fuses.

148. This requirement will render the use of p.v.c. insulated cables uneconomic for most uses, except possibly for road lighting circuits which involve a number of terminations and joints.

149. Because there is no metallic sheath with p.v.c. insulated cables, special attention is necessary to ensure satisfactory earth continuity of the wire armouring at joints and terminations, and care should be taken to ensure that the joint resistance of the armouring does not exceed that of an equivalent length of complete wire armouring.

M.I.M.S. cables

150. Mineral insulated copper sheathed cables with p.v.c. serving are available in current ratings up to approximately 100A, two core, and 70A, three core. For a given current rating the cost is approximately comparable with that of armoured p.v.c. cables but they have far superior heat resisting properties.

151. Special non-ferrous connectors should be used for underground joints and the joints should be enclosed in p.v.c. sleeves with the ends bound and sealed or otherwise protected to exclude moisture.

Minimum bending radii for cables

152. The minimum recommended insulation radii for different types of cable are as follows:

Armoured p.v.c.	8 × dia. of cable
Paper insulated lead sheathed	12 × „ „ „
Aluminium sheathed cables up to 1¼ in. dia.	12 × „ „ „
Aluminium sheathed cables over 1¼ in. dia. up to 2 in. dia.	15 × „ „ „
Aluminium sheathed cables over 2 in. dia.	18 × „ „ „
m.i.m.s. cables (copper and aluminium types)	6 × „ „ „

XX. Internal Medium Voltage distribution feeders

General

153. The types of cable mentioned for external feeders are suitable for internal distribution feeders and the comments are generally applicable. Except in damp and corrosive areas, internal feeders will not require to be served overall. Where serving is considered to be necessary, p.v.c. serving should be specified. Compounded fibrous types of serving are highly flammable and should not be used on internal feeders.

154. Because of their superior fire resisting properties, busbar trunking and m.i.m.s. cables are recommended for rising mains in hospitals.

Busbar trunking systems

155. Busbar trunking distribution systems can accommodate subsequent modifications and additions to the installation much more flexibily than other types of distribution feeders; they may also be economical for larger feeders, and are particularly suitable for vertical and for mainly straight horizontal feeders.

156. Particular attention should be given to voltage drop with busbar feeders, since the increased spacing between conductors increases the reactance, so that the voltage drop is slightly higher than that of cables having closely spaced conductors of equivalent current carrying capacity.

157. Higher operating temperatures are permissible, but it is important that the insulation of cable terminations and connections to the busbars should be suitable for the maximum operating temperature of the busbars or be removed for 6 in. as is necessary to comply with No. 211, (c) of the I.E.E. Regulations.

158. For a given current rating, aluminium conductors are approximately half the weight of and are slightly cheaper than copper conductors. They also have greater mechanical strength. This is a particular advantage for vertical feeders, and for smaller sizes.

159. Smaller copper conductors (e.g. those less than $\frac{3}{8}$ in. dia.) should be sleeved throughout their length, but sleeving can usually be omitted from larger copper conductors and from aluminium conductors.

160. Because of the differing maximum permissible current density of copper and aluminium conductors, the most convenient material to use for a given application may be decided by the standard busbar size having the nearest convenient current rating. Typical sizes and current ratings of copper and aluminium busbars are given in Appendix IV.

161. Plug-in type busbar systems are available which enable connections to be made or broken whilst the busbars are energised, but for normal hospital applications this facility will not be required and busbar systems employing permanent connections will be satisfactory.

162. B.S.159 is primarily applicable to busbars for use with switchgear but is in part applicable to distribution busbars and compliance with this standard should be specified as far as it is applicable.

163. Long busbar installations should incorporate expansion couplings at suitable intervals to allow the bar to expand in both directions. The maximum straight length of busbar which is permissible without an expansion coupling will vary with different types of support and should be in accordance with the manufacturers' recommendations.

164. The spacing of insulators along the conductors should suit the m.p.f.e. of the system. 24 in. spacings are typical and should be suitable for fault energies which are liable to be experienced with m.v. systems supplied from 500 kVA transformers.

165. Special attention should be given to earthing continuity of heavy current busbar trunking because of the high prospective fault energy. With trunking housing busbars having a current rating exceeding 200A a continuous tinned copper bonding strip with bonding links at the joints of the trunking should be used to supplement the earth continuity. The current carrying capacity of the earthing continuity system should comply with table 4 of the I.E.E. regulations.

166. Fire barriers should be inserted in trunking where it penetrates floors and partitions which themselves are intended to form fire barriers.

M.I.M.S. cables

167. Mineral insulated (magnesium oxide) cables are available with copper conductors and sheaths and with aluminium conductors and sheaths. For a given current rating the aluminium type is slightly cheaper than the copper in sizes up to 150A. Lightness is the chief merit of aluminium type mineral insulated cable—the saving in weight is approximately 33%. They will also withstand a higher sustained temperature than the copper type without deterioration, but this aspect is unlikely to be significant for hospital applications since copper grades are quite suitable for temperatures up to 200 °C.

168. Aluminium sheaths are less resistant to corrosion than copper and unless weight considerations are important the latter would normally be used.

169. Mineral insulated cables should comply with B.S.3207.

170. The following grades are available:

Type of Conductor	*Grade*	*Maximum size*	*Current rating (amps) at 40 °C.*
Copper	440 V.	1 × 0·007 sq. in.	48
,,	,,	4 × 0·002 ,, ,,	14
Aluminium	,,	1 × 0·01 ,, ,,	46
,,	,,	4 × 0·003 ,, ,,	16
Copper	660 V.	1 × 0·2 ,, ,,	400
,,	,,	4 × 0·0225 ,, ,,	70
Aluminium	,,	1 × 0·1 ,, ,,	200
,,	,,	4 × 0·0145 ,, ,,	45

171. In smaller sizes, mineral insulated cables are more expensive than p.v.c. or v.r.i. cables of similar current carrying capacity installed in steel conduit, but compare favourably in larger sizes, particularly when one takes into account the lower installation costs and their longer life. M.I.M.S. cables can also be re-used if necessary on rearrangement of the installation. They are particularly suitable for sub-main circuits which are not sufficiently numerous to justify the use of steel trunking. 440 V grade should be used in the sizes in which it is available.

172. Standard (unserved) cables are suitable for most hospital applications. They should not, however, be used in damp or corrosive areas where copper type cables with p.v.c. serving, at approximately 10% extra cost, should be specified.

173. Where single core cables are used for heavy current circuits, cables of different phases should be laid in close proximity (preferably in trefoil formation) and other appropriate steps taken to reduce eddy currents e.g., by the use of non-ferrous fittings at terminations, and by making slots between the hole and the outer edge of any ferrous plates through which the cables pass.

174. Fixing distances should be in accordance with manufacturers' recommendations.

175. Cable trays can simplify installation where several cables are to be installed in close proximity. They should have a rust resisting non-metallic finish in order to reduce the risk of damage by electrolytic action (e.g., two coats of bitumastic paint).

176. Magnesium oxide readily absorbs moisture and it is important that the correct seals, fittings and accessories as supplied by the manufacturers are used. It is also advisable to use the special installation tools supplied by the manufacturers and to follow their advice concerning the use of temporary sealing.

Cables in conduit and trunking

177. The grades of cables normally used are rubber insulated cables to B.S.7, p.v.c. insulated cables to B.S.2004 and butyl rubber insulated cables to B.S.3387. Experience indicates that p.v.c. cables are preferable for ambient temperature conditions within the range 0—45 °C. P.V.C. cables should not be used where ambient temperatures below 0 °C are likely. Rubber insulated cables are preferable for such conditions.

178. Butyl rubber insulated cables are inferior in mechanical strength to p.v.c. and v.r.i. cables and their use should normally be restricted to situations where high ambient temperatures are likely. They are suitable for use in ambient temperatures up to 95 °C. and under conditions where the conductor temperature will not exceed 100 °C.

179. Silicone rubber insulated cables complying with B.S.3258 are suitable for use with conductor temperatures up to 150 °C. In general, however, the use of silicone rubber insulated cables will be limited since m.i.m.s. cables will normally be used where temperature conditions of this order are liable to occur.

180. Cables installed in conduit sizes $\frac{3}{4}$ in. and 1 in., or in trunking where there are sufficient circuits to justify its use, represent the most economical type of installation. This type of installation has an average useful life of approximately 30 years with p.v.c. cables and somewhat less with other forms of wiring. Conduit installations are less flexible than trunking where there will be subsequent alterations and additions. Conduit smaller than $\frac{3}{4}$ in. should not normally be used.

181. Conduit should be heavy gauge quality to B.S.31, class B. Enamel finish is satisfactory for dry situations. Galvanised quality should be specified where damp conditions are likely. All conduit threads exposed after installation should be coated with a rust-resisting paint.

182. As far as is practicable conduits should be continuous between outlets, and factory made bends, tees, etc. should not be used. Conduit fittings should be of malleable cast iron to B.S.31. Conduits should be swabbed through before wiring is commenced.

Under-floor steel trunking and duct systems

183. Under-floor trunking and duct systems are usually more expensive than alternative methods of installation (e.g. buried conduits or overhead trunking). There is also a greater risk of damage caused by water entering through inspection covers of under-floor systems. It is recommended, therefore, that this system should not be used where suitable alternative methods of installation can be utilised.

184. Where drawing-in of cables is necessary, the space factor of wiring in ducts should not exceed 35%, to comply with No. 223 of the I.E.E. Regulations.

Cable trunking

185. Cable trunking is available in sizes from $1\frac{1}{2}$ in. × $1\frac{1}{2}$ in. to 9 in. × 4 in. and represents the cheapest type of installation where a number of circuits can conveniently follow the same path. A minimum gauge of

16 s.w.g. is recommended. Cable trunking is suitable for use in voids above suspended ceilings, surface applications and use in vertical ducts. Trunking layouts should be pre-determined and be dimensionally co-ordinated with other building components to enable standard prefabricated lengths to be used whenever practicable.

186. Unnecessary segregation of circuits should be avoided. For example, lighting and power circuits can be installed in the same trunking or conduit. Emergency supply circuits should be kept separate so that there is adequate fire protection between these circuits and those of the normal installation. Extra low voltage wiring can be installed with that operating at mains potential provided that the insulation is satisfactory for the maximum voltage present.

187. Where segregation is necessary, partitioned trunking is usually less expensive to instal than separate trunking installed side by side.

188. Cables installed in trunking should be laced or clipped together in convenient groups at suitable intervals and labelled to assist identification of circuits. Adequate space should be allowed for future additions. The space factor for wiring in trunking should not exceed 45%.

189. Trunking should have a suitable anti-rust finish (for example, zinc-coated sheet steel) with stove-enamel finish. For damp situations, galvanised trunking should be specified.

190. Jointing surfaces should be free of enamel finish to ensure satisfactory earthing continuity between sections. On sizes larger than 3 in. × 2 in. copper bonding links should be used.

XXI. Medium Voltage switchboards

General

191. Unit type switchboards show a saving in cost of approximately 33% compared with cubicle type boards of equal specifications and tend to be more flexible as regards future alterations and additions. Apart from neater appearance, cubicle switchboards have no significant advantage and unit boards will be suitable for most hospital applications.

192. The switch and fuse-gear should be capable of handling safely the m.p.f.e. of the system. Where the switchboard is supplied direct from a h.v. transformer having a capacity not exceeding 500 kVA, switch and fuse-gear having a 25 MVA rating will normally be suitable.

193. Where the supply is obtained direct from an Area Board sub-station or from a medium voltage network the m.p.f.e. should be verified with the authority and the MVA rating of the switch and fuse-gear specified accordingly.

Switchgear

194. Experience has shown that air break switches complying with B.S.861 and air break circuit breakers complying with B.S.862 are generally satisfactory. Thus in order to reduce the fire risk, oil switchgear should not normally be used within the size range available for air break types, i.e. up to 800A for fuse-switches and up to 1600A for circuit breakers.

195. Where a transformer supplies only one switchboard it will not normally be necessary to provide circuit protection and isolating facilities on the secondary side of the transformer. The primary isolator can be used to isolate the busbars from the supply.

196. On main switchboards where high fault currents are possible, high fault making and high load breaking combined fuse-switches having fully shielded live contacts will normally be used. Small fuse-switch units for use where high MVA ratings are necessary are uneconomical and should be avoided where practicable (e.g. by the use of a larger fuse-switch unit and a sub-main fuse board). Fuse-switch units smaller than 30A. should not normally be used.

Fuses

197. Fuses on main distribution switchboards should be of a high rupturing capacity, non-deteriorating type and have an MVA rating appropriate to the m.p.f.e. of the system. They should comply with B.S.88.

198. The steps in fuse sizes which are necessary to ensure effective fault discrimination between main and sub-main circuit fusing will vary with the m.p.f.e. of the system and it is advisable to consult the fuse manufacturer where discrimination is important.

Busbar chambers

199. Busbars should be totally enclosed in a housing constructed of rust proofed sheet steel and the minimum clearances should comply with B.S.159. Chambers housing three phase conductors should be clearly and indelibly marked " Danger . . . . volts."

Busbar conductors and connections

200. Busbars and busbar connections should comply with B.S.159.

201. Switchboard busbars will normally consist of hard-drawn high conductivity copper or aluminium to B.S.2898. and be mounted on shock resisting non-tracking type insulators.

202. Insulator spacings will vary with the type of insulator and the MVA rating. It should be verified with the manufacturer that the size of busbar, type of insulator and insulator spacing have been type tested to withstand the m.p.f.e. of the system.

203. The use of busbars having current ratings in excess of 1,600A is not recommended for hospital applications.

204. Busbars of rectangular or circular cross-section are satisfactory. Details of the a.c. current rating for enclosed busbars for indoor use are given in Appendix IV. The busbars should be arranged to allow the largest size conductors to be connected without undue bending. The neutral bar will normally be located at the bottom.

205. Connectors should be of the split clamping type to eliminate drilling of busbars and should be used with an appropriately rated cable sweating socket or compression type connector where a special crimping tool is available. Connectors having current ratings exceeding 100A should have an integral clamp and cable connector. Connections between busbars and sub-main control units should consist of high conductivity copper rods or strips having a current rating not less than that of the fuse-switches or circuit breakers controlling the sub-main circuits, and not less than half the current rating of the fuses or a quarter the operating current of the circuit breaker protecting the busbars (this is to meet the requirements of No. 108 of the I.E.E. Regulations).

206. The length and current rating of busbars should allow for possible future additions to the switchboard or, alternatively, the design should be such as to facilitate the extension of the busbars to meet possible future requirements. The initial capacity of busbars should be adequate for foreseeable future requirements and the need for subsequent additional laminations should not normally arise.

207. Switchboard busbars need not be fully sheathed with insulation, but if painted dull black, heat dissipation is improved. Conspicuous colour markings (e.g. p.v.c. sleeves) should be provided on each section of busbars for phase identification.

Meters

208. Main distribution switchboards should be equipped with an ammeter and four suitably rated current transformers together with a selector switch to enable the current loading of each phase, and of the neutral, to be selected. A voltmeter should also be specified together with a selector switch to enable the voltages between each phase and neutral to be selected.

209. Energy meters, complying with B.S.37, should be specified where these are required for costing purposes. Indicating instruments should comply with B.S.89. Industrial Grade, 4 in. dial instruments are normally considered satisfactory.

210. Current transformers for use with instruments should comply with B.S.81.

Switchboard framing

211. Switchboard framing should be rigidly constructed of suitable steel sections and arranged for floor mounting and/or wall fixing. Adequate space should be allowed to enable future additions to be made to the switchboard. A typical switchboard is shown in figure 21.

Sub-distribution centres

212. Sub-distribution equipment should be housed in a suitable enclosure arranged so as to allow easy and convenient access to the switch and fusegear from a standing position. The enclosure should not be used for any other purpose and should have adequate fire resisting separation from any corridor or staircase forming a recognised means of escape from the premises.

213. Sub-distribution enclosures should be fitted with locks to prevent unauthorised interference, the locks being common throughout the installation.

214. Typical examples of sub-distribution centres are shown in figures 14 and 15.

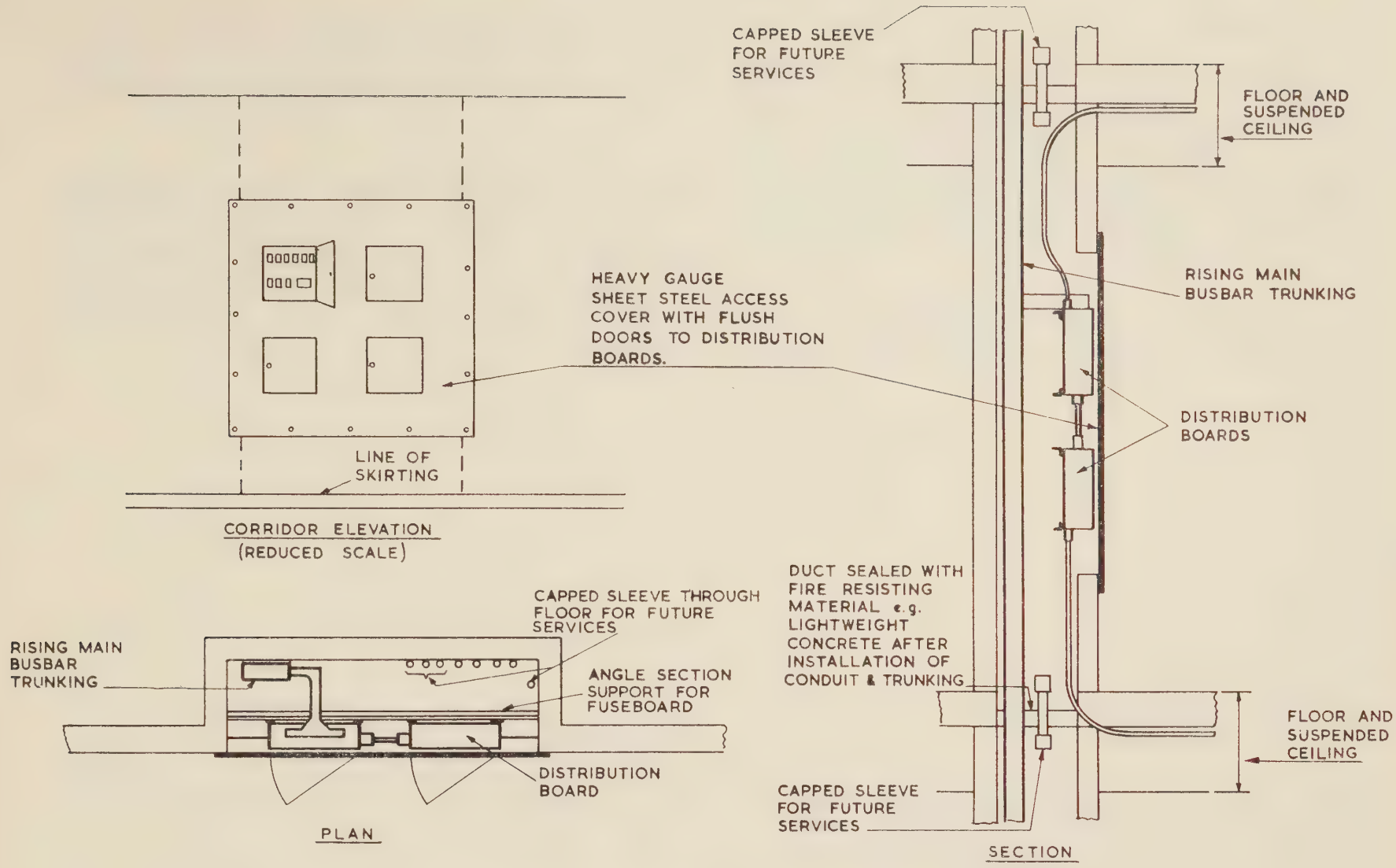

CAPPED SLEEVE FOR FUTURE SERVICES
FLOOR AND SUSPENDED CEILING
HEAVY GAUGE SHEET STEEL ACCESS COVER WITH FLUSH DOORS TO DISTRIBUTION BOARDS.
RISING MAIN BUSBAR TRUNKING
DISTRIBUTION BOARDS
LINE OF SKIRTING
CORRIDOR ELEVATION (REDUCED SCALE)
DUCT SEALED WITH FIRE RESISTING MATERIAL e.g. LIGHTWEIGHT CONCRETE AFTER INSTALLATION OF CONDUIT & TRUNKING
CAPPED SLEEVE THROUGH FLOOR FOR FUTURE SERVICES
RISING MAIN BUSBAR TRUNKING
ANGLE SECTION SUPPORT FOR FUSEBOARD
DISTRIBUTION BOARD
PLAN
FLOOR AND SUSPENDED CEILING
CAPPED SLEEVE FOR FUTURE SERVICES
SECTION

Figure 14. Sub-distribution centre incorporated in rising main duct.

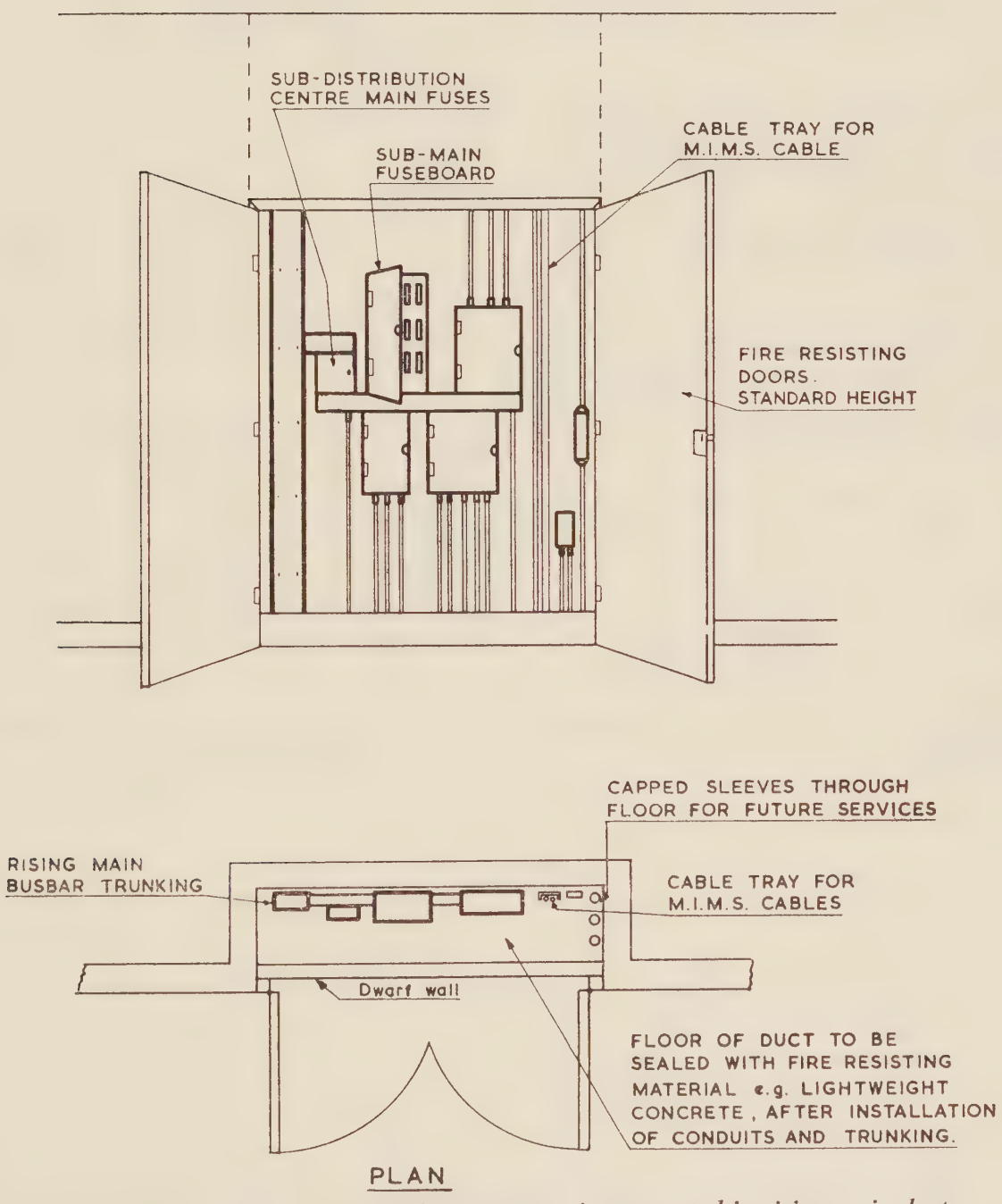

SUB-DISTRIBUTION CENTRE MAIN FUSES
SUB-MAIN FUSEBOARD
CABLE TRAY FOR M.I.M.S. CABLE
FIRE RESISTING DOORS. STANDARD HEIGHT
CAPPED SLEEVES THROUGH FLOOR FOR FUTURE SERVICES
RISING MAIN BUSBAR TRUNKING
CABLE TRAY FOR M.I.M.S. CABLES
Dwarf wall
FLOOR OF DUCT TO BE SEALED WITH FIRE RESISTING MATERIAL e.g. LIGHTWEIGHT CONCRETE, AFTER INSTALLATION OF CONDUITS AND TRUNKING.
PLAN

Figure 15. Typical sub-distribution centre incorporated in rising main duct.

Feeder pillars

215. In general, particularly in new hospitals, it will be possible to make indoor facilities available to house sub-distribution equipment. Instances may arise, however, where it will be convenient and economical to employ outdoor feeder pillars where a feeder is used to supply several peripheral buildings, e.g. staff accommodation or workshops.

216. The fuses or circuit breakers used for protecting the distribution feeders should be of a type similar to those used for other sub-distribution circuit protection and spare fuses should be accommodated in the pillars. It will not usually be necessary to fuse the incoming feeder.

217. As there is no nationally accepted standard for feeder pillars, details of cable terminations, busbars and safety arrangements (including the shielding of busbars and live connections and, where necessary, anti-condensation heating) should be covered by specification.

XXII. Earthing

218. Because of difficulties associated with overlapping resistance areas, and in order to reduce the earthing impedance as far as is possible, it is recommended that only one good low resistance earth electrode system be provided for each sub-station and used for earthing the transformer neutral and metal work associated with the medium voltage distribution.

219. The earth loop impedance should satisfy the basic earthing requirements of the I.E.E. Regulations, i.e. it should be capable of passing a current equivalent to three times the rating of the largest fuse or one and a half times that of the highest circuit breaker setting.

220. It is usually desirable to provide a main earth busbar mounted on insulators in a convenient position in the sub-station (e.g. in the transformer chamber or m.v. switchroom) with connections to the transformers etc. as follows:

(i) insulated stranded cable connections to the transformer neutrals;

(ii) bare conductors to transformer frames;

(iii) bare conductor to h.v. switchgear frame;

(iv) bare conductor to m.v. switchgear frame;

(v) insulated stranded conductor to sub-station earth electrode(s);

221. Figure 16 shows a typical sub-station earthing system.

222. The recommended size of earth continuity conductors is as follows:

Maximum prospective fault current	*Insulated stranded conductor*	*Bare conductor*
14 kA.	37/·072 in.	1 in. × $\frac{3}{16}$ in. copper
9 kA	19/·083 in.	1 in. × $\frac{1}{8}$ in. copper

223. Where necessary, earthing connections should be protected against mechanical damage and corrosion.

224. Buried earthing connections (e.g., to the earth electrodes) should be protected from corrosion by a suitable compound and installed so as to be reasonably accessible for inspection. The use of materials which are liable in juxtoposition to give rise to significant electro-chemical potentials (e.g. copper and zinc) should be avoided, particularly in damp situations.

225. Earthing will be dealt with in more detail in a separate Technical Memorandum.

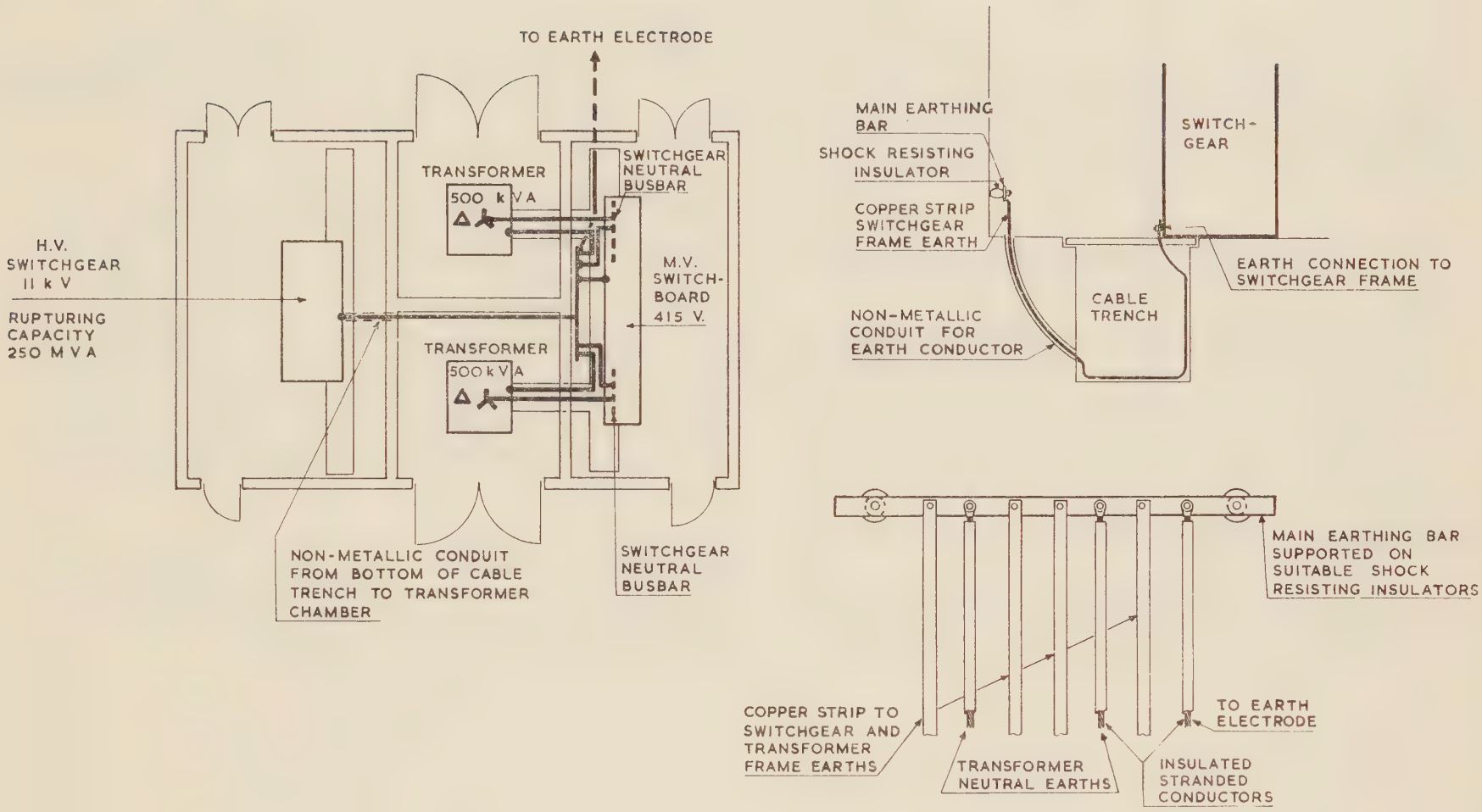


Figure 16. Sub-station earthing.

XXIII. Record drawings

226. A copy of each working drawing, including wiring diagrams of special control equipment etc. which are supplied by manufacturers, amended to show any alterations which have been made during installation, is needed as an accurate transparent linen record drawing of the completed installation.

227. A linen print of these record drawings should be supplied to the Superintendent Engineer and Hospital Engineer, who will be responsible for maintaining the installation.

XXIV. Handing-over procedure

228. There should be a formal handing-over procedure which should include a thorough inspection of the installation and the witnessing of tests by a team competent to assess the quality and accuracy of the work.

229. The team would normally consist of the following:

Engineer representing the authority responsible for preparing the specification and supervising the work.

Representative of the electrical contractor(s).

Engineer representing the hospital authority concerned.

Representative of the architect.

230. Lists of any deficiences or rejected items relating to the work carried out by the electrical contractor, or building work associated with the electrical installation, should be compiled at the end of the defects liability period.

231. Retention moneys, as determined in the contract, should be paid over at the satisfactory rectification of defects. This should also cover items provided by nominated suppliers.

232. When the installation has been completed in accordance with the specification a take-over certificate should be issued certifying the date on which the work was taken over and the commencement of the maintenance period.

233. Wiring diagrams, instructional manuals, etc. should be given to the taking-over authority at or before the final handing-over meeting.

Appendix 1

High voltage sub-stations

Siting

234. Where practicable, transformer sub-stations should be installed at ground floor level. Because of restricted access for fire fighting and the possibility of flooding, basement sites should be avoided.

235. Although it is desirable to site sub-stations as near as possible to the load centre to be served, it is also necessary to consider the fire risk to other parts of the hospital and nuisance from noise. Whenever practicable h.v. sub-stations should not be located in main hospital buildings and should be far enough away from wards and operating theatre suites to avoid any possibility of noise nuisance.

Access

236. Sub-stations should be accessible from a road to allow easy access for transformer changing, fire appliances, maintenance vehicles, etc.

Layout

237. The layout should allow adequate space for drawing-in and terminating cables and for servicing purposes. Where future additions are likely to be required adequate space should also be allowed. Head room should be sufficient to ensure adequate cooling. Typical layouts are shown in figures 17-20.

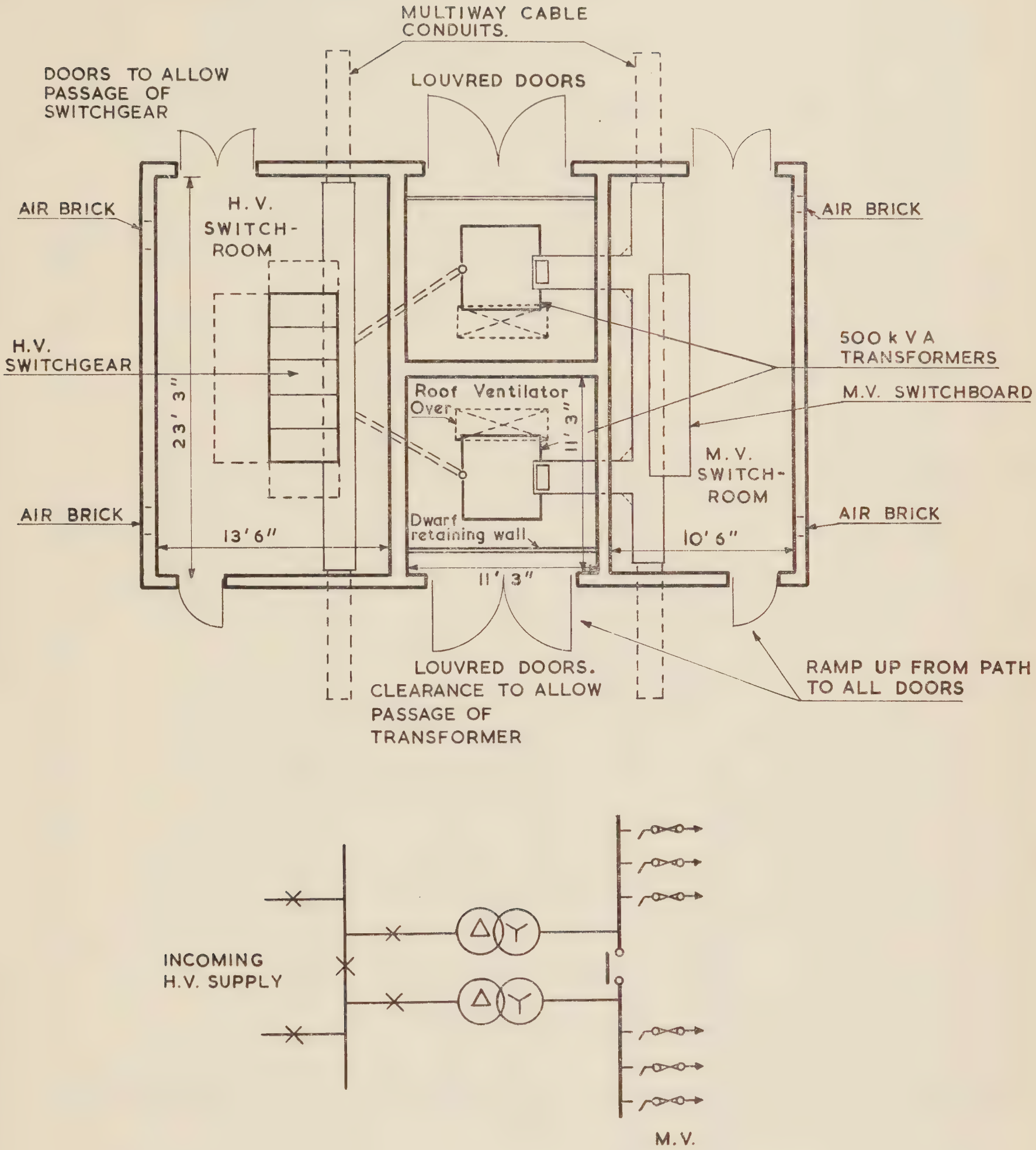
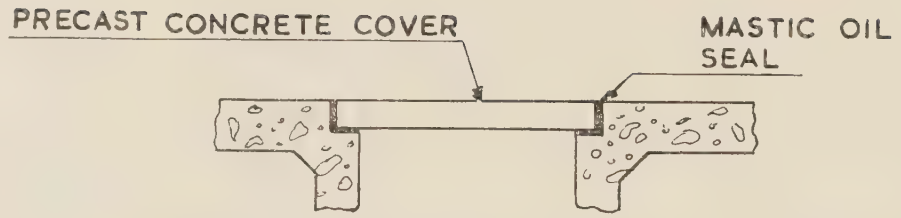
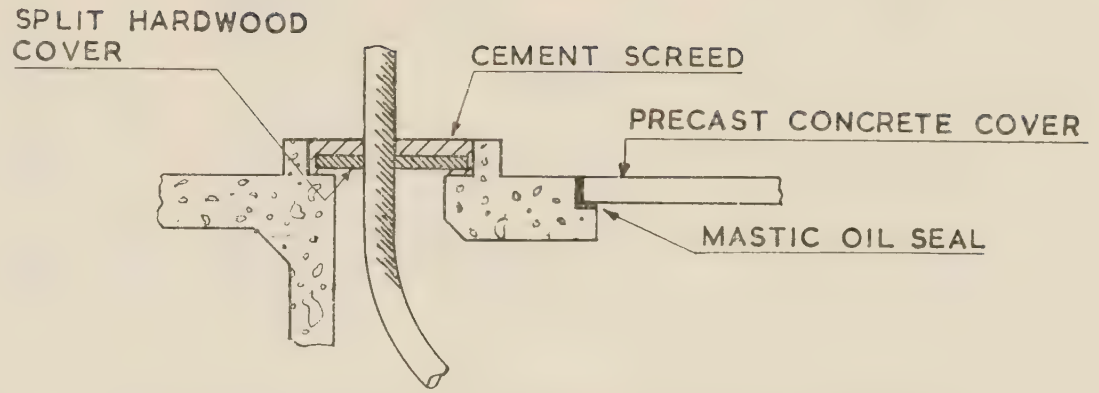


Figure 17. Typical layout of a two-transformer sub-station as a separate building.



TRENCH COVER AND SEAL IN H.V. SWITCH ROOM AND TRANSFORMER ROOMS.



DETAIL OF CABLE TRENCH AT POSITION 'A'

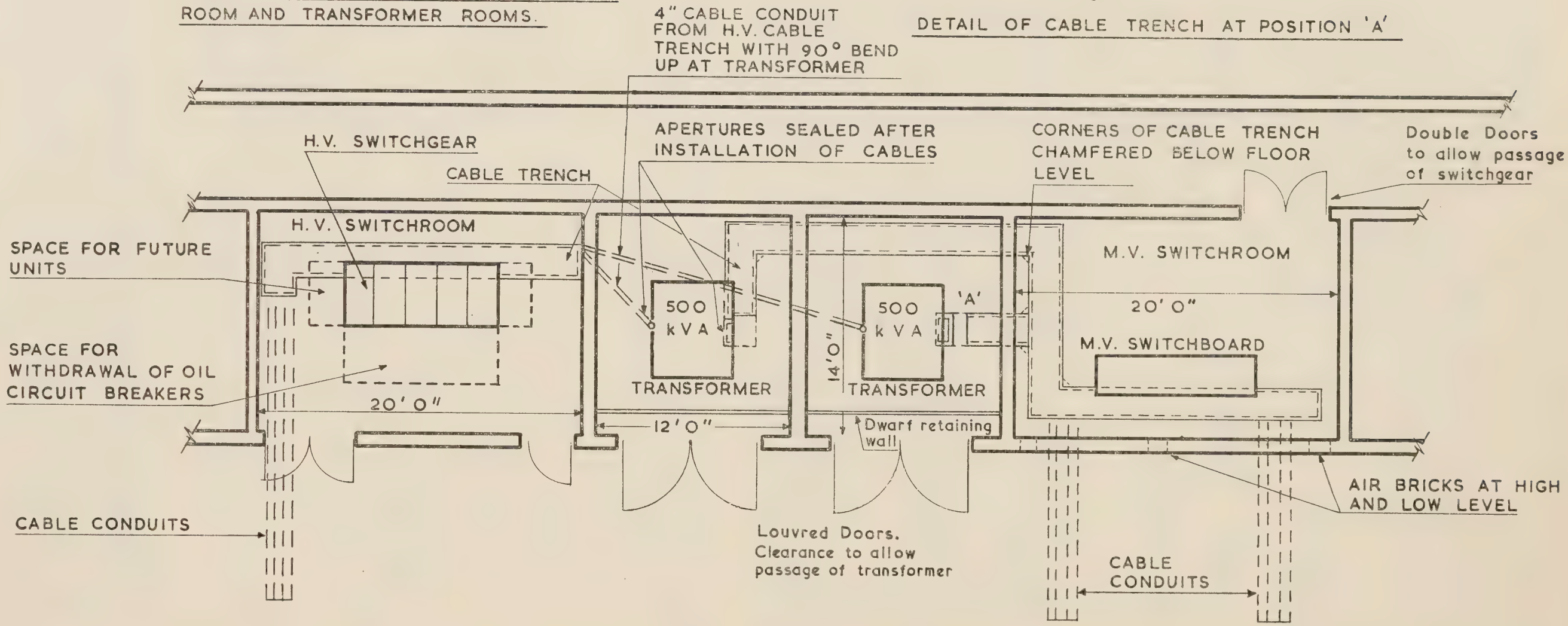


Figure 18. Typical layout of a two-transformer sub-station incorporated in a hospital building.

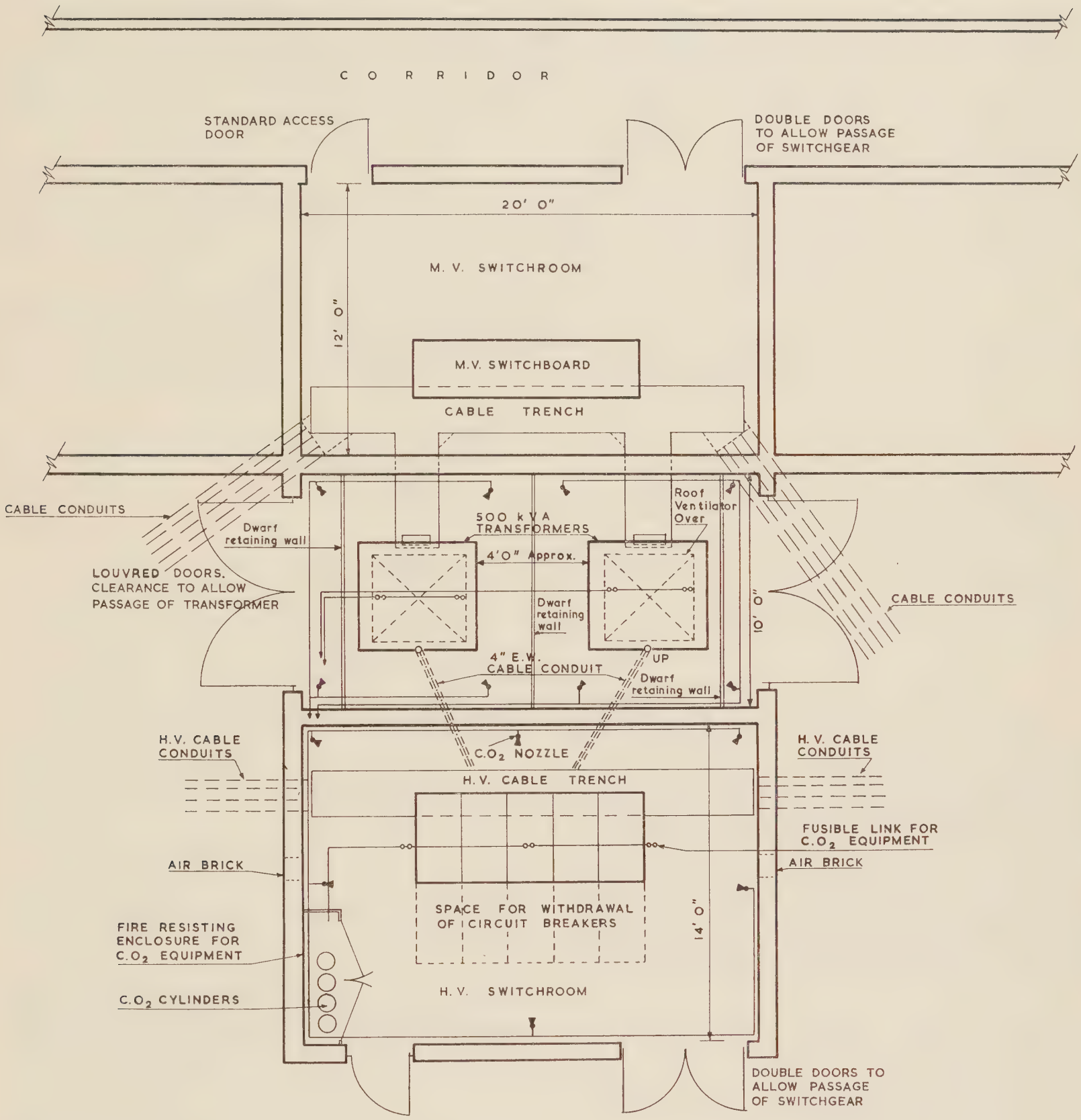
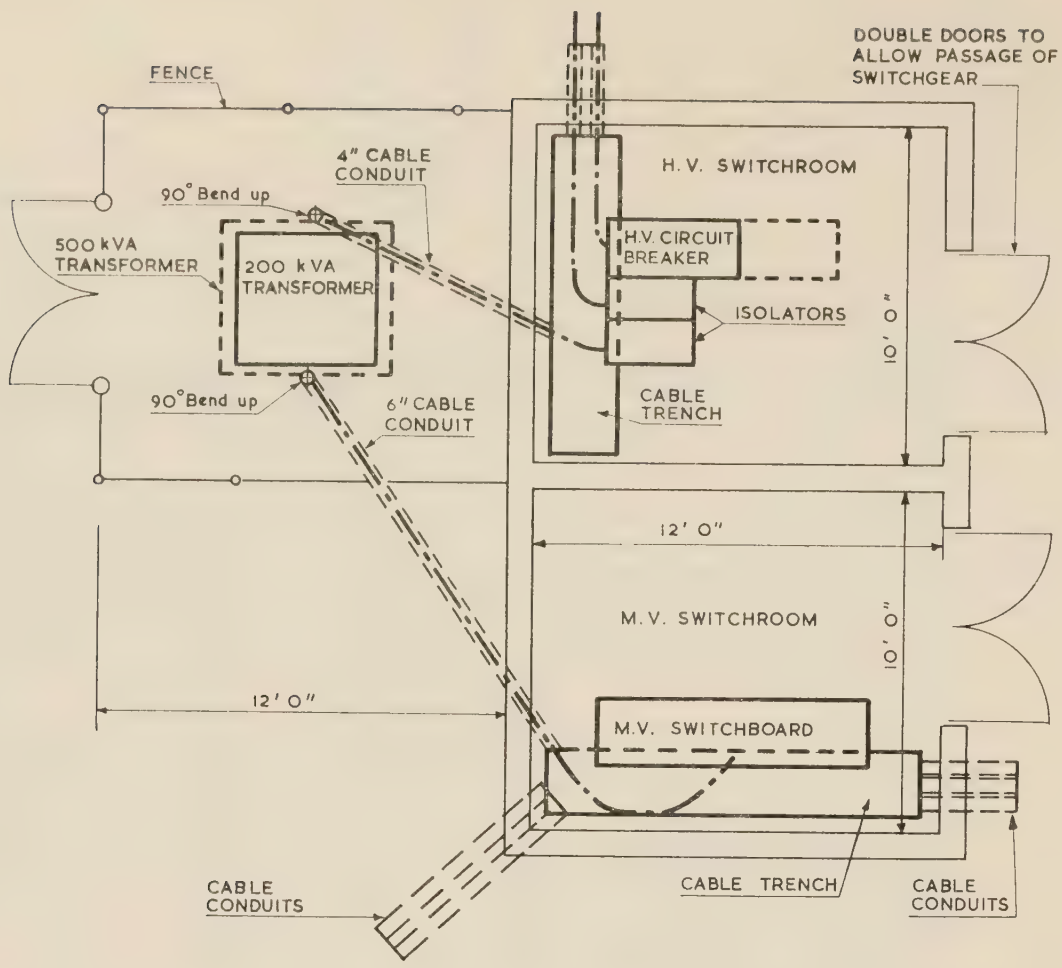


Figure 19. Typical example of a two-transformer sub-station with medium voltage switchroom only, incorporated in a hospital building.



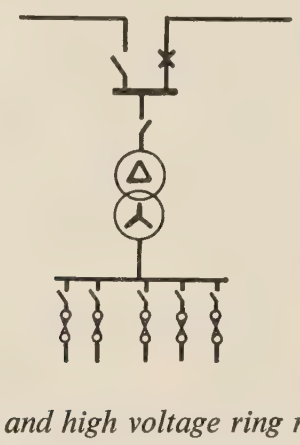


Figure 20. Small sub-station with outdoor transformer and high voltage ring main unit switchgear.

238. It is not necessary to provide sufficient head room and a lifting beam to facilitate the removal of a transformer from its tank whilst inside the chamber. With the present-day reliability of transformers it should rarely be necessary to do this; if it is, the transformer can be moved into the open air and a crane used. The cabling and ducts should be so arranged as to avoid obstruction to the removal of the transformer.

239. The following minimum clearances are recommended:

Between adjacent transformers—4 ft.

Between transformer and wall—3 ft.

Head room above transformer tank—5 ft.

Between rear of h.v. and m.v. switchgear and wall—2 ft. 6 in.

Between front of h.v. switchgear and wall—3 ft. + 3 ft. for withdrawing switchgear.

240. As far as practicable all equipment should be accessible from floor level.

241. Where it is essential to install above normal reach, equipment which is liable to require servicing, permanent access facilities (e.g. a fixed hard-wood stand) should be provided.

Construction

242. The following minimum construction requirements are suggested:

Walls and fire-resisting partitions forming the chamber: 9 in. brickwork, or equivalent fire resisting construction. Internal walls should have a suitable finish to reduce dust formation and facilitate cleaning.

243. Floors and ceilings—5 in. re-inforced concrete or equivalent fire resisting construction. Floors should have a non-slip, dust reducing finish.

244. Doors should open outwards and allow sufficient clearance for transformers.

245. In order to minimise solar heat gain, windows should not be provided in transformer chambers.

246. It is unnecessary to incorporate a weak panel for explosion relief.

Oil retaining arrangements

247. Transformer chambers which will house oil-immersed transformers should have retaining walls or similar provision, finished to prevent oil spreading in the event of leakage. Retaining arrangements should be capable of holding the total oil content of the transformers and are preferable to underground oil pits.

248. The retaining arrangements should not impede the removal of the transformer.

249. H.V. switchrooms should have a slight fall in the floor or other similar provision to prevent oil spreading beyond the chamber.

Ducts

250. Cable trenches and ducts should be so constructed as to avoid providing paths along which leaking oil will travel.

251. They should have a fire-resisting barrier (e.g. sand blocks) where they pass beneath walls and partitions which themselves form fire resisting barriers between parts of the building.

252. External cable ducts and conduits should be sealed where they enter buildings to prevent ingress of water and vermin.

Fire protection

253. The fire risk associated with good quality oil circuit breakers and transformers is slight but it is important that reasonable precautions are taken to prevent the spread of fire to other h.v. units and to other parts of the hospital in the event of a failure of one unit. In addition to the fire resisting separation between transformer chambers and h.v. switchrooms and adjoining parts of the hospital, there should be adequate fire resisting separation between units or, alternatively, fixed automatic fire-extinguishing apparatus. Fixed fire extinguishing equipment need not be provided where each transformer is housed in a separate cell of fire-resisting construction or where h.v. switchgear units are separated by suitable fire-resisting partititions.

254. H.V. and m.v. cables should be installed in separate ducts or conduits with adequate fire resisting separation between them, and fire resisting separation should be provided between m.v. feeders where two or more transformers are installed. The flammable serving should be removed from cables inside the building to reduce the fire risk. Exposed portions of cables should be wrapped with asbestos tape as additional fire and mechanical protection.

Trip switches

255. Where automatic fire extinguishing precautions are not provided it may be desirable to provide remote tripping of circuit breakers, e.g. by means of trip switches placed outside the fire risk zone. The switches should be housed in breakable glass-fronted boxes and have a permanent and conspicuous notice giving instructions on their use and details of the circuits controlled. Where installed in the open they should be weatherproof.

Ventilation

256. The copper and iron losses of a transformer amount to approximately 2 kW per 100 kVA so that transformer chambers should be adequately ventilated direct to the outer air to prevent excessive temperature rise.

257. Where practicable, the ventilation should be arranged with low level inlet openings on one side of the chamber, and high level openings on the other side or in the roof to ensure good cross-ventilation over the transformer cooling tubes. As a general guide, a ratio of 1 sq. ft. of inlet and outlet ventilation openings for each 100 kVA transformer capacity is suggested. It is frequently convenient to provide louvres in the lower part of external doors for the input ventilation, with high level wall-mounted louvres or penthouse louvres as outlet ventilation.

258. H.V. switchrooms should also have permanent inlet and outlet ventilation direct to the outer air, e.g. 12 in. air bricks.

Heating

259. H.V. switchrooms should be provided with thermostatically controlled heating which is capable of maintaining the temperature of the switchroom at not less than 50 °F with an outdoor temperature of 32 °F. Where electric heating is used, the heaters should be permanently installed and should be of a totally enclosed low temperature type.

Lighting

260. Adequate levels of illumination should be provided in the plant rooms and because of intermittent use tungsten filament lamp lighting will be satisfactory. The suggested average level of illumination in the h.v. switchroom and transformer chamber is 10 lumens per sq. ft.

261. The lighting fittings in the switchroom should be arranged to give good illumination to the front of the switchboard.

Socket outlets

262. Each room should be equipped with both universal type mains sockets and extra-low voltage sockets to allow the convenient use of portable tools and 12 volt hand-lamps. Because of the possibility of high fault energies the circuits should be protected with h.r.c. fuses.

Fire extinguishing apparatus

263. Transformer chambers housing more than one oil-cooled transformer, and h.v. switchrooms without fire-resisting separation between the switch units, should be equipped with CO_2 fire extinguishing installations arranged for fusible link and manual operation. A separate installation should be provided in each room requiring protection.

264. Fusible links having an operating temperature of 155 °F should be placed at ceiling level over each transformer and over each switchgear bank and should be arranged to operate a CO_2 release valve and a switch connected with the hospital fire warning system. The link lines should consist of non-ferrous flexible cord installed in ¾ in. galvanised quality steel conduit. A safety catch should be provided to prevent inadvertant operation during maintenance and a conspicuous notice should be provided drawing attention to this.

265. The manual release should be housed in a glass-fronted box mounted outside the access door to the chamber. It should be painted red and its use clearly indicated.

266. The cylinders of liquified CO_2 should comply with B.S.401 and should be mounted vertically in a suitable rack located outside the fire risk area.

267. The quantity of CO_2 should be on the basis of one 80 lb cylinder for each 800 cu. ft. of room volume to be protected.

268. Discharge nozzles should be located at a high level and connected to the release valve by means of steel piping complying with B.S.1387 galvanised heavy quality type. The spacing of discharge nozzles will depend on the type selected and should be arranged in accordance with the manufacturer's recommendations.

Warning notices, etc.

269. Conspicuous and indelible notices " Danger—High Voltage " should be provided on doors giving access to h.v. equipment and on doors to rooms containing h.v. equipment.

270. An indelible notice " CO_2 " in six inch red letters on a white background should be fixed on the outside of doors giving access to rooms having CO_2 installations in addition to the " Danger—High Voltage " warning notice.

271. Instructions as to treatment of persons suffering from electric shock should be exhibited in the substation (see Form 731, H.M. Stationery Office).

Appendix II

Medium Voltage switchrooms

Siting

272. Switchrooms should be sited as close as possible to the load centre and arranged to allow convenient direct entry to rising ducts, horizontal ducts, crawlways, etc.

Layout

273. The layout should allow adequate space around the switchboard for servicing purposes. Suggested minimum clearances between the switchboard and walls are 2 ft. 6 in. at the rear and 3 ft. in front, plus additional space required for any withdrawable switchgear. Where provision is made for busbars to be extended, adequate space should be allowed at one end of the switchboard for this purpose. Figure 21 shows a typical m.v. switchroom.

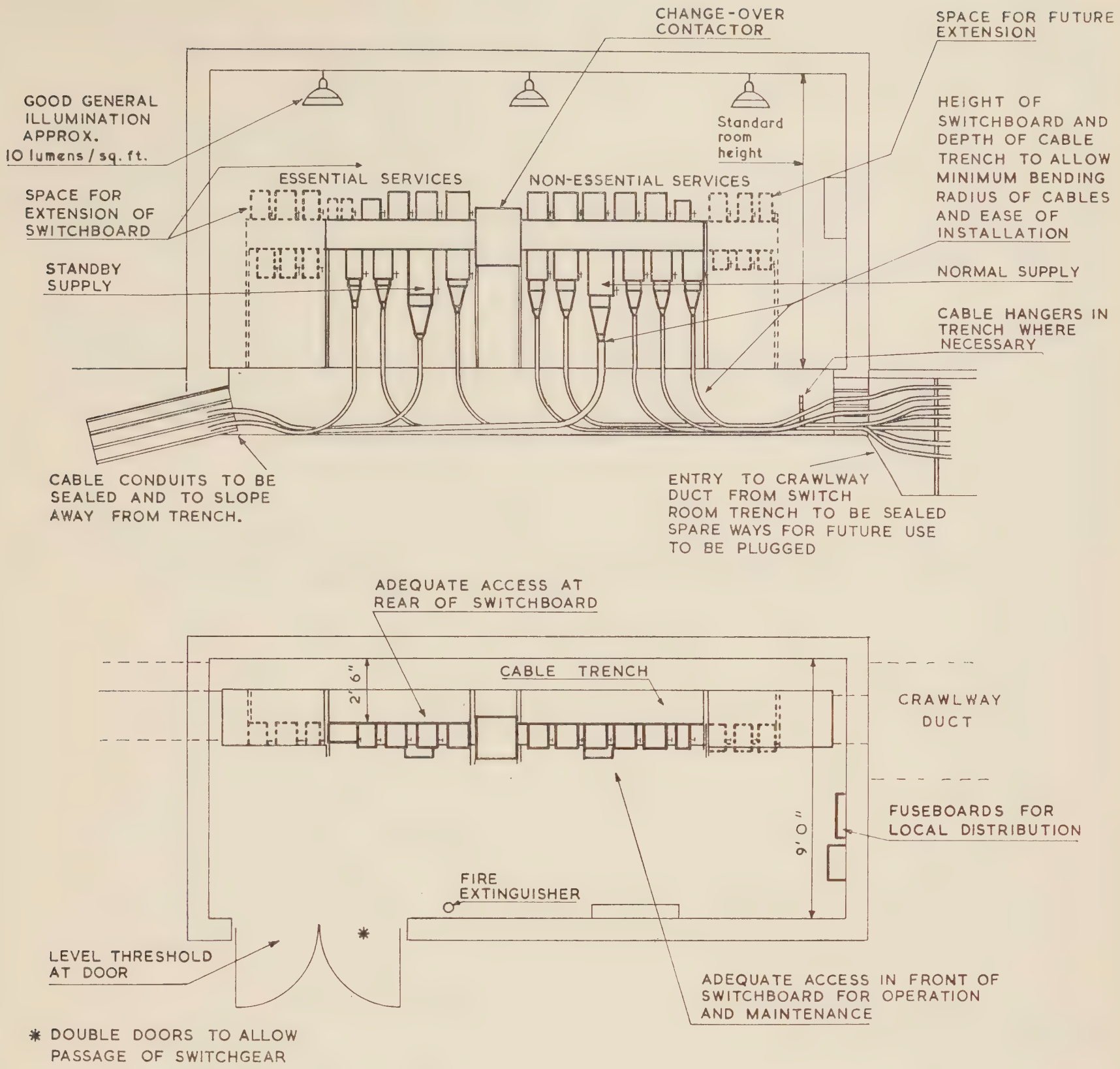

CHANGE-OVER CONTACTOR
SPACE FOR FUTURE EXTENSION
GOOD GENERAL ILLUMINATION APPROX. 10 lumens / sq. ft.
Standard room height
HEIGHT OF SWITCHBOARD AND DEPTH OF CABLE TRENCH TO ALLOW MINIMUM BENDING RADIUS OF CABLES AND EASE OF INSTALLATION
ESSENTIAL SERVICES
NON-ESSENTIAL SERVICES
SPACE FOR EXTENSION OF SWITCHBOARD
STANDBY SUPPLY
NORMAL SUPPLY
CABLE HANGERS IN TRENCH WHERE NECESSARY
CABLE CONDUITS TO BE SEALED AND TO SLOPE AWAY FROM TRENCH.
ENTRY TO CRAWLWAY DUCT FROM SWITCH ROOM TRENCH TO BE SEALED SPARE WAYS FOR FUTURE USE TO BE PLUGGED
ADEQUATE ACCESS AT REAR OF SWITCHBOARD
2'6"
CABLE TRENCH
CRAWLWAY DUCT
9'0"
FUSEBOARDS FOR LOCAL DISTRIBUTION
FIRE EXTINGUISHER
LEVEL THRESHOLD AT DOOR
ADEQUATE ACCESS IN FRONT OF SWITCHBOARD FOR OPERATION AND MAINTENANCE
* DOUBLE DOORS TO ALLOW PASSAGE OF SWITCHGEAR

Figure 21. Typical medium voltage switchroom.

Floor

274. The floors should have a non-slip, dust-reducing finish.

Walls

275. As a minimum requirement internal walls should be fair faced brickwork painted to reduce dust formation and facilitate cleaning. Highly flammable wall finishes should be avoided.

Trenches

276. Under-floor trenches with removable covers will normally be required to accommodate incoming and distribution cables.

Separation of supplies

277. Where the switchboard consists of two or more main sections, with inter-connection switchgear for emergency use only, the main feeder cables should be kept apart as far as is practicable to eliminate the possibility of a fault on one service affecting the other service cables.

Rubber mats

278. Rubber mats complying with B.S.921 should be provided along the front of the switchboard.

Heating

279. To reduce the possibility of condensation, m.v. switchrooms should be provided with thermostatically controlled heating designed to prevent the temperature falling below 50 °F., with an outdoor temperature of 32 °F. Where electric heating is used the heaters should be of a totally enclosed low temperature type, rigidly fixed in position, and connected to the supply by permanently installed wiring.

Ventilation

280. The switchroom should be provided with permanent inlet and outlet ventilation direct to the outer air (e.g., 12 in. × 12 in. air bricks).

Lighting

281. A good standard of illumination should be provided in the m.v. switchroom. A minimum of 10 lumens per square foot in the working area is suggested. The lighting fittings should be arranged to give good illumination to the front of the switchboard.

Socket outlets

282. Mains universal type sockets and extra low voltage sockets should be provided to allow the convenient use of portable tools and 12 V. hand-lamps. Because of the possibility of high fault energies the circuit should be protected with h.r.c. fuses.

Marking

283. All switchgear should be clearly and indelibly marked, e.g., by engraved labels indicating the circuits controlled. " DANGER . . . . . volts " markings should be provided on panels, etc. giving access to live conductors operating at potentials exceeding 250 V.

Wiring diagram

284. A schematic single line diagram, e.g., black on white linen print, framed and glazed, should be provided in a conspicuous position in the switchroom to show clearly the function of all switch and fuse-gear. This will assist in clearing faults with the minimum of delay.

Spares, tools, etc.

285. Adequate spare fuses and other essential spare parts, rubber gloves complying with B.S.697 and any special tools which are liable to be required for emergency use should be provided in a special cabinet or other reserved place.

Electric shock

286. A notice giving instructions for treating electric shock should be exhibited in the switchroom (see Form 731, H.M. Stationery Office).

Appendix III

Service ducts

General

287. In general, it is preferable to have a few large ducts rather than a number of smaller ducts, since small ducts allow less flexibility.

288. Duct accommodation should enable the planned services to be installed with adequate clearances and should include space for possible future requirements. As far as is practicable ducts for the accommodation of electrical services should not be used for other services. Where it is necessary to accommodate electrical and other services on the same duct there should be adequate separation between these services and electric cables, and conduits. The electrical services should be installed in the upper part of the duct to minimise the possibility of damage from water.

289. Where busbars are installed in ducts with other services they should be separately totally enclosed, e.g., in steel trunking. " DANGER . . . . . volts " notices should be provided at points where access to busbars can be obtained.

Lift shafts

290. Lift shafts should not be used for the accommodation of rising mains.

Construction

291. Floors of ducts, etc., should be constructed of concrete and have a slight fall and a shallow drainage channel with drainage points at suitable intervals. Sides should be constructed of concrete or brick.

292. Access openings should be large enough to enable standard lengths of conduit (14ft. approx.) to be installed and removed without bending and should be kept clear of conduits and cables. Figure 22 illustrates the principles which should govern the layout of crawlways, subways and service voids.

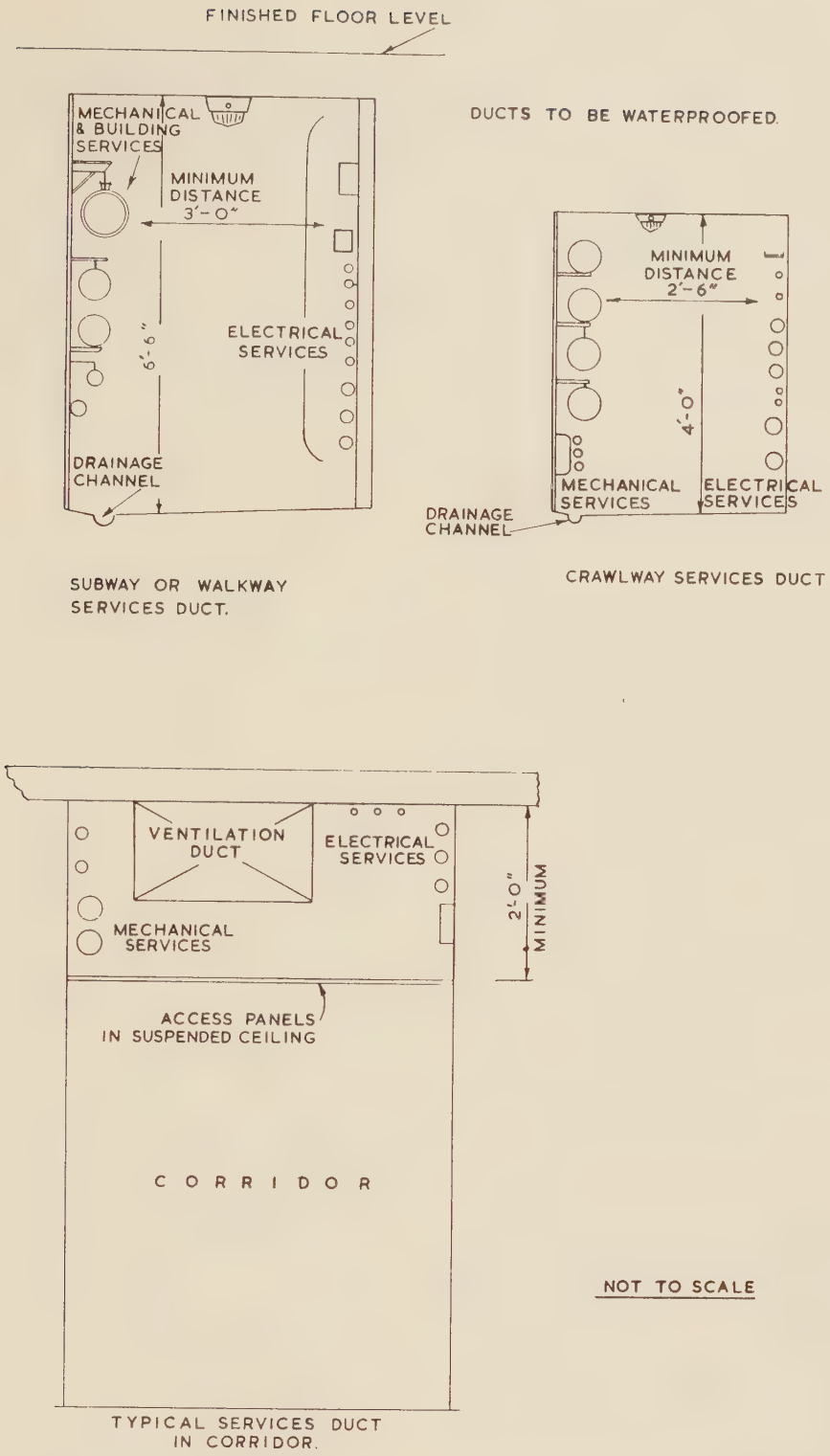


Figure 22. Typical ducts for services.

External cable runs

293. Single cables where installed in open ground should be laid in sifted soil or sand and be protected with concrete interlocking cover tiles. Accurately located cable run markers should be provided where practicable.

294. On main cable runs where additional cables may subsequently be required, conduits should be installed to avoid re-excavation.

295. Conduits should be used at all points where cables enter buildings and the entry points should be sealed after laying to prevent the passage of moisture and vermin.

296. Conduits should also be used where cables pass under roads or other areas having a permanent made-up surface and should be protected with concrete to prevent fracture by traffic. Spare capacity should be allowed for possible future requirements.

297. Asbestos cement conduits are less expensive than glazed earthenware and have a lower co-efficient of friction. They will be suitable for most applications. Bitumen dipped conduits should be used where water-proofing is necessary (e.g. at entry points to buildings).

298. Conduits should be "rodded" before pulling-in cables.

299. Recommended minimum depths for external cable installations are:

M.V. cables 2 ft. 6 in.

H.V. cables 3 ft. 0 in.

Cable plan

300. A plan (linen print, framed and glazed) showing accurately the position of all external cable runs, conduits, etc., together with all external drainage facilities, should be displayed in a prominent position, e.g. in the m.v. switchroom.

Appendix IV

Typical sizes and ratings for Copper and Aluminium busbars for medium voltage A.C. switchboards and distribution centres

Current rating (amperes)	Copper		Aluminium	
	Busbar size	Approximate cross-sectional area	Busbar size	Approximate cross-sectional area
200	$\frac{3}{4}$ in. × $\frac{3}{16}$ in.	0·14 sq. ins.	1 in. × $\frac{1}{4}$ in.	0·25 sq. ins.
200	$\frac{7}{16}$ in. dia.	0·15 „ „	$\frac{5}{8}$ in. dia.	0·31 „ „
400	$1\frac{1}{4}$ in. × $\frac{1}{4}$ in.	0·31 „ „	$1\frac{1}{2}$ in. × $\frac{3}{8}$ in.	0·56 „ „
400	1 in. × $\frac{3}{8}$ in.	0·375 „ „	$1\frac{3}{4}$ in. × $\frac{1}{4}$ in.	0·44 „ „
400	$\frac{3}{4}$ in. dia.	0·44 „ „	1 in. dia.	0·79 „ „
600	2 in. × $\frac{1}{4}$ in.	0·5 „ „	2—$1\frac{1}{2}$ in. × $\frac{1}{4}$ in.	0·75 „ „
600	$1\frac{1}{2}$ in. × $\frac{3}{8}$ in.	0·56 „ „		
600	1 in. dia.	0·79 „ „		
800	2—$1\frac{1}{2}$ in. × $\frac{1}{4}$ in.	0·75 „ „	2—$1\frac{1}{2}$ in. × $\frac{3}{8}$ in.	1·125 „ „
800	$1\frac{1}{4}$ in. dia.	1·23 „ „		
1200	2—$2\frac{1}{2}$ in. × $\frac{1}{4}$ in.	1·25 „ „	2—$2\frac{1}{2}$ in. × $\frac{3}{8}$ in.	1·88 „ „
1600	2—$2\frac{3}{4}$ in. × $\frac{3}{8}$ in.	2·06 „ „	2—$3\frac{1}{2}$ in. × $\frac{3}{8}$ in.	2·625 „ „

Notes

1. Numerous busbar conductor sections are available and the ratings given above are representative examples for general guidance.

2. The ratings are based on a maximum temperature rise of 50 °C for busbars installed in a sheet steel enclosure, in ambient temperatures up to 35 °C. The ratings for rectangular bars are applicable to bars installed horizontally on edge. Where duplicate bars are used it is assumed that the spacing between the bars is equal to the thickness of the bars.

3. An assurance should be obtained from the manufacturer that busbar arrangements similar to those specified, i.e. as regards size of busbar, type and spacing of insulators, have been type tested as described in B.S.159, to withstand fault currents equal to the m.p.f.e. of the system.

4. Additional information on busbars is available in the following publications:

"Copper for Busbars" (Copper Development Association)

"Aluminium Busbar"—*A. G. Thomas and P.J.H. Rata*—Alcan Industries Ltd.

Appendix V

Medium voltage cable joints

General

301. The information given in this Appendix is based on the Central Electricity Authority and Area Boards' Code of Practice on the design of cable joints for paper insulated lead covered and armoured cables with copper conductors for voltages up to 650 V.

302. Straight through and simple tee joints only are dealt with: double tee and breeches joints are not recommended for hospital applications.

303. Underground joints in paper insulated cables, having either copper or aluminium conductors, should be enclosed in compound filled, plumbed lead, lead alloy or tinned copper sleeves or tee boxes. The sleeves should be enclosed in compound filled cast iron or concrete outer protection boxes. Cast iron boxes should have 2 coats of bituminous paint.

304. Mechanically bonded boxes in lieu of a plumbed box should not be used for underground applications.

Sweated conductor joints

305. Each straight-through conductor joint should be sweated with the aid of a copper ferrule which may be of the grooved type so that it can be closed tightly around the ends of the two conductors to be joined. The copper ferrule should be made of wrought copper, annealed and tinned after forming, having a sectional area of not less than the sectional area of the conductor for which it is designed. Tee conductor joints may be of the married type or sweated with the aid of a tinned annealed wrought copper connector arranged to clamp tightly around the conductors to be joined.

Aluminium joints

306. Aluminium type cables tend to be more difficult to joint than copper conductor types and the work should be carried out by jointers who are trained in the technique.

Soldering aluminium conductors

307. The fluxes used in aluminium conductor joints may be either organic or inorganic type. With either type of flux adequate ventilation at the place of work is desirable to avoid discomfort to the jointer caused by inhaling fumes from the heated flux. It is essential to specify that only jointers trained in aluminium soldering techniques are employed and that the proper materials and correct temperatures are used. The jointing procedure depends on the flux and solder used and the manufacturers' instructions should be followed. Cadmium-free solder has been recommended by the N.J.A.C. and should always be used.

Compression joints

308. Compression jointing of aluminium and copper conductors when carried out with the special tools which are available for this purpose has proved to be mechanically and electrically satisfactory. With paper insulated cables a plumber jointer will be required for the metal sheath and it will normally, therefore, be convenient to use soldered joints for the conductors. Where p.v.c. insulated tails are used, however, compression joints will be necessary to avoid the use of heat.

Terminations

309. Terminations should be made in compound filled sealing boxes. Tailless terminations should be completely compound filled (apart from the expansion chamber). Where connecting tails are required the cable ends should be soldered solid and p.v.c. insulated tails joined by suitable compression jointing sleeves. The joints should be insulated with varnished cambric or other suitable insulation appropriate to the working voltage and overwrapped with bitumastic tape or similar waterproof binding. The compound filling should generously cover the paper insulation. The tails should be colour coded to indicate the phase and neutral conductors.

310. The metal sheath of the cable should be sweated to the brass cone of the wiping gland and the armouring secured under a bonding clamp which has a good metallic connection with the cable sealing box to ensure proper earthing continuity.

Solder

311. The solder used for making copper conductor joints should be Grade "M" or Grade "G" complying with the requirements of B.S.219.

Insulation

312. Conductor joint insulation should be factory impregnated cotton tape, wrapped around the ferrule to a build-up thickness equal to not less than one and a half times the thickness of the cable core insulation, the jointed cores being finally bound together by a wrapping of similar tape.

Lead sleeves for straight through joints

313. The lead sleeves for straight through joints should be of solid drawn seamless lead tube made by the extrusion process and should comply with the minimum dimensions given in figure 23.

Tee joint boxes

314. Boxes for tee joints should be of lead or copper complying with the minimum dimensions given in figure 25. Lead boxes should be formed from extruded lead sheath, or alternatively of non-porous cast lead. Pressed copper boxes should be tinned.

Filling holes

315. Unless otherwise specified, each lead sleeve or lead or copper tee box should be provided with compound filling holes, sufficiently large in diameter to ensure easy filling of the joint. Caps should be supplied for plumbing over these holes after filling the joint with compound.

Plumbing metal

316. The solder to be used for plumbing the lead sleeve or tee box to the lead sheath of the cable should be Grade 'D', complying with the requirements of B.S.219.

Sleeve filling compound.

317. The sleeve or tee box filling compound should be of the asphaltic bitumen base type complying with the requirements of B.S.1858.

Outer protection boxes

318. Outer protection boxes should be of cast iron, concrete or earthenware. Cast iron protection boxes should be of such dimensions as will provide not less than $\frac{3}{8}$ in. of compound filling space around the encased sleeve and the internal length should be at least 2 in. greater than the overall length of the sleeve. Where used on tee boxes, the internal length should be at least 2 in. greater on the "main" and 1 in. greater on the "tee", measured from the centre line of the "main" cable.

319. The diameters of the cable entries should be greater than the overall diameter of the largest size of

cable included in the range for a particular size of protection box.

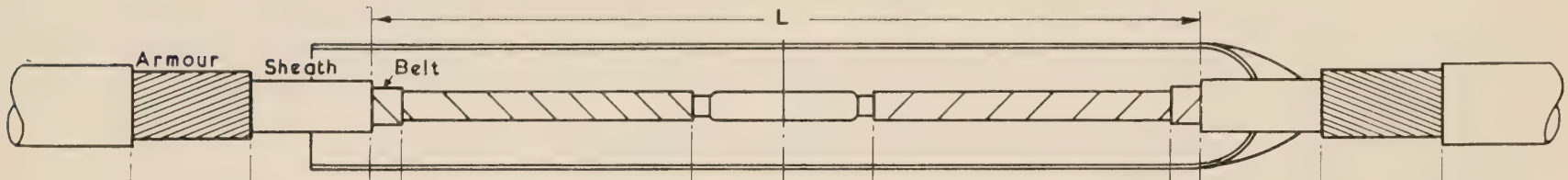
320. Cast iron protection boxes should be divided along the centre line and provided with deep tongued and grooved or other approved joints. The clamping bolts for securing the two half boxes should be so arranged that they can be readily removed after slackening. Suitable armour clamps should be provided on the box extremities for ensuring the efficient mechanical and electrical bonding of the armour across the joint. The compound filling holes should each be not less than 3 sq. in. in area and provided with suitable cover plates. As a protection against rust, all cast iron boxes should be given two coats of bituminous paint.

321. Reinforced concrete protection boxes (e.g. as illustrated in figures 24 and 25) should comply with the minimum dimensions given.

Protection box filling compounds

322. The protection box filling compound should be of refined bitumen or other approved compound.

STRAIGHT THROUGH JOINTS (PLUMBED TYPE)

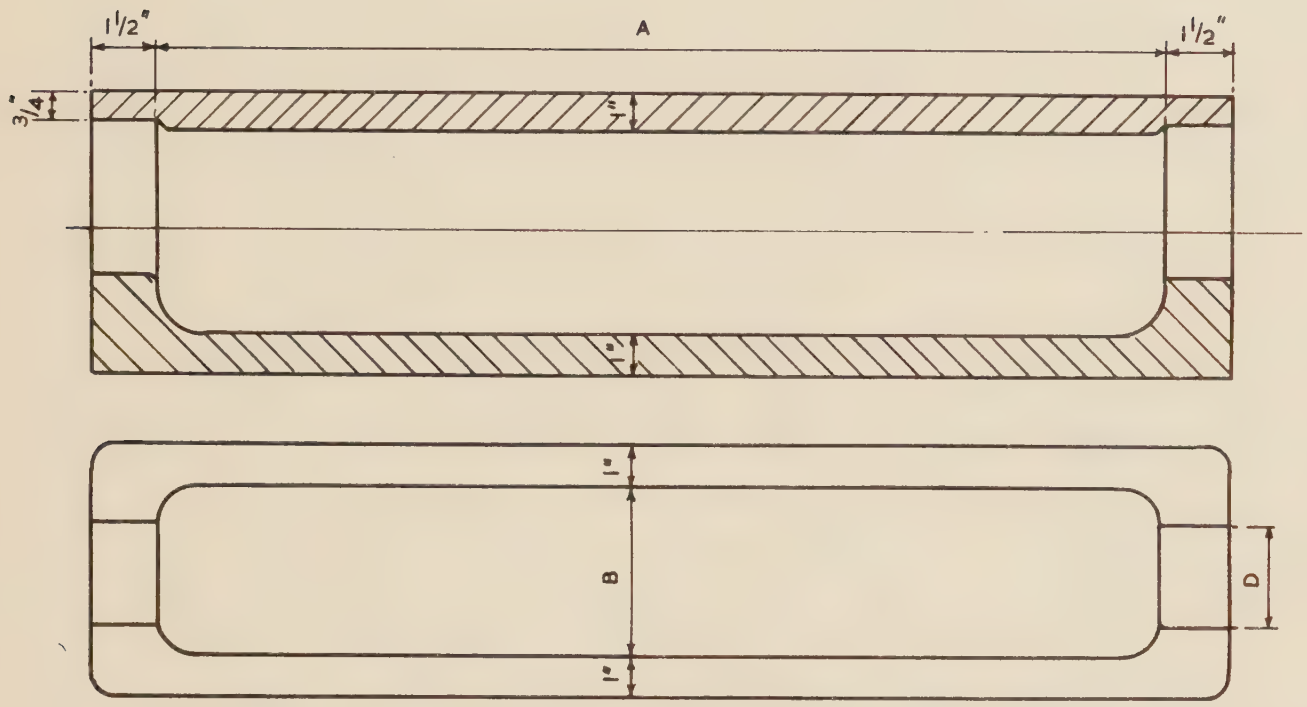


CABLE SIZE SQ. IN.		IN. MINIMUM	IN.	Lead Sleeve Dimensions In. Minimum * Internal Dia. In.	Length before Dressing Down.	Thickness In.	IN.	IN.	Protection Box Type See Fig 24	IN.	IN. MINIMUM		Lead Cut Dimension "L" In.
0·0225 4core	TO SUIT OUTER PROTECTION BOX	2	½	2	13"	0·100	¾	¾	S.T. 1	½	2	TO SUIT OUTER PROTECTION BOX.	11
·04 4core		2	½	3	18"	0·100	¾	¾	S.T. 2	½	2		16
·06 4core		2	½	3	18"	0·100	⅞	⅞	S.T. 2.	½	2		16
0·1 4core		2	½	3	18"	0·100	1	1	S.T. 2.	½	2		16
0·15 4core		2	½	3½	22"	0·125	1 3/16	1 3/16	S.T. 3	½	2		20
0·2 4core		2	½	3½	22"	0·125	1¼	1¼	S.T. 3	½	2		20
0·25 4core		2	½	4	23"	0·125	1⅜	1⅜	S.T. 4	½	2		21
0·3 4core		2	½	4	23"	0·125	1½	1½	S.T. 4	½	2		21
0·4 4core		2	½	5	25"	0·150	1 11/16	1 11/16	S.T. 5.	½	2		23
0·5 4core		2	½	5	25"	0·150	1⅞	1⅞	S.T. 5.	½	2		23

NOTE. THIS SKETCH FOR CLARITY DEPICTS A SINGLE CORE CABLE BUT THE DIMENSIONS APPLY EQUALLY TO MULTICORE CABLES.

* NOTE THESE SLEEVES ARE SUITABLE FOR JOINTS WHERE THE CORES REQUIRE TO BE CROSSED.

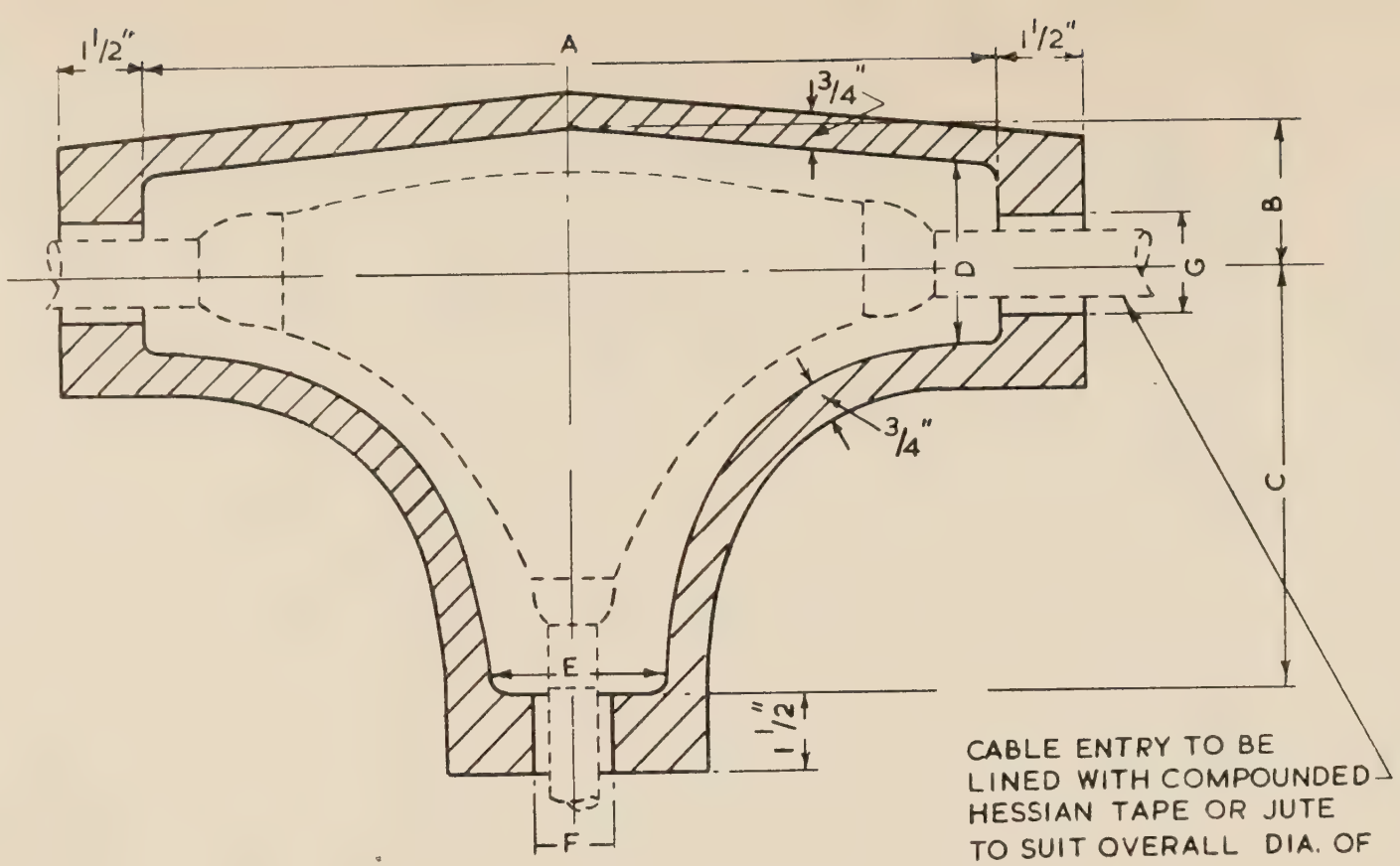
Figure 23. Dimensions for medium voltage straight through cable joints.



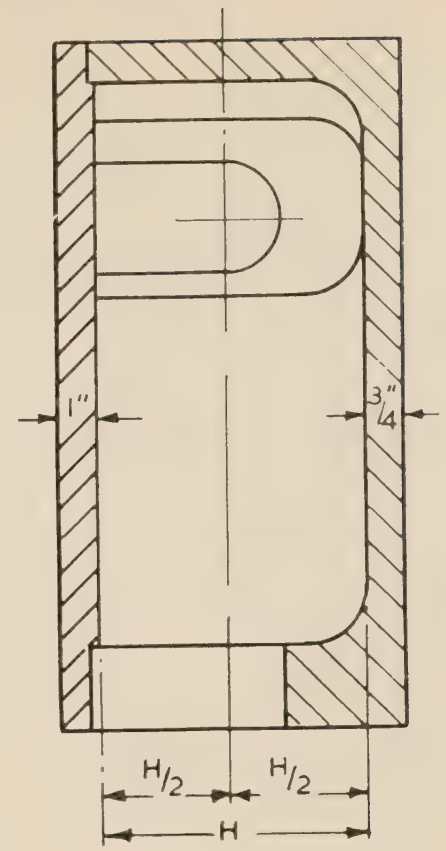
CABLE ENTRY TO BE LINED WITH COMPOUNDED HESSIAN TAPE OR JUTE TO SUIT DIAMETER OF CABLE.

BOX TYPE	LEAD SLEEVE		A	B	C	D
	Approx. DIA. IN.	Approx. LENGTH IN.				
S.T. 1.	2 1/2	15	18"	3 1/2"	4"	1 1/2"
S.T.2	3 1/4	19	24"	4 1/2"	5"	2 1/2"
S.T.3	3 3/4	21 1/2	28"	5"	5"	3"
S.T.4	4 1/2	24 1/2	31"	5 1/2"	5 1/2"	3 1/2"
S.T.6.	4 3/4	26 1/2	34"	6 1/2"	6 1/2"	3 3/4"

Figure 24. Concrete protection box suitable for straight through joints showing minimum dimensions and general arrangement.



THIRD ANGLE PROJECTION



Minimum Dimensions for Lead or Copper (Plumbed Type) Tee Boxes

Maximum Cable Size		Internal Length on Main (in.)	Internal Length on Tee (in.)*	Internal Depth at Filling Hole (in.)	Thickness (in)		Concrete Protection Box Dimensions (in.)								
Main	Tee				Lead	Copper	Box Type	A	B	C	D	E	F	G	H
0·1 sq. in 4 core	0·1 sq. in 2c 0·04 sq. in 4c	$10\frac{1}{4}$	$4\frac{11}{16}$	$3\frac{1}{4}$	0·085	0·02	T.1	16	$2\frac{1}{2}$	8	$3\frac{1}{2}$	$3\frac{1}{2}$	2	$2\frac{1}{2}$	5
0·15 sq. in 4 core	0·06 sq. in 2c 0·04 sq. in 4c	$11\frac{1}{2}$	6	$3\frac{1}{2}$	0·085	0·02	T.1	16	$2\frac{1}{2}$	8	$3\frac{1}{2}$	$3\frac{1}{2}$	2	$2\frac{1}{2}$	5
0·2 sq. in 4 core	0·1 sq. in 2c 0·04 sq. in 4c	$12\frac{3}{4}$	$5\frac{9}{16}$	$3\frac{1}{2}$	0·085	0·02	T.1	16	$2\frac{1}{2}$	8	$3\frac{1}{2}$	$3\frac{1}{2}$	2	$2\frac{1}{2}$	5
0·3 sq. in 4 core	0·15 sq. in 2c 0·06 sq. in 4c	$15\frac{1}{2}$	$6\frac{7}{8}$	$4\frac{1}{2}$	0·100	0·02	T.2	23	$3\frac{1}{2}$	$11\frac{1}{2}$	5	4	$2\frac{1}{2}$	3	6

* NOTE: These Dimensions are from the centre line of the main cable to the extremity of the shell on the tee.

Figure 25. Dimensions for medium voltage tee joints with concrete protection box.

Appendix VI

High voltage cable joints

323. The information given in this Appendix is based on the Electricity Council Code of Practice on the design of h.v. cable joints (Engineering Recommendation C34).

324. The Appendix deals only with straight through joints for paper insulated, belted, metal sheathed cables with conductors of equal size and operating at 11,000V. It covers the requirements for joints in armoured or unarmoured cables having lead or aluminium sheaths with copper or aluminium conductors.

Conductors of equal sizes

325. Each straight through copper or aluminium conductor joint should be sweated with the aid of a ferrule so arranged that it can be fitted closely round the ends of the two conductors to be joined. Copper ferrules, which should be made of wrought copper annealed and tinned, may be used with copper or aluminium conductors. Aluminium ferrules should only be used with aluminium conductors and should be tinned. The cross sectional area of any ferrule should be not less than that of the conductor for which it is designed.

Soldering copper conductors

326. The solder used for making copper conductor joints should be Grade "M" or Grade "G" complying with the requirements of B.S.219. The flux to be used should be powdered resin or other non-corrosive flux. In order to ensure that the solder penetrates to all parts of the joint, both conductors should be tinned before the ferrule is fitted.

Soldering aluminium conductors

327. The fluxes to be used for making aluminium conductor joints may be either organic or inorganic. With either type of flux adequate ventilation at the place of work is desirable to avoid discomfort to the jointer caused by inhaling fumes from the heated flux. It is essential to specify that jointers trained in aluminium soldering techniques are employed and that the proper materials and correct temperatures are used. The jointing procedure to be followed depends on the flux and solder used and the manufacturer's instructions should be followed. Cadmium-free solder has been recommended by the N.J.A.C. and should always be used.

Insulation of joints on belted cables.

328. The insulation of the jointed conductors should consist of either:

(*a*) Factory impregnated cotton tape or paper cotton tape wrapped around each jointed conductor to a built-up thickness over the ferrule equal to not less than one and a half times the thickness of the cable core insulation;

(*b*) Factory impregnated paper rolls of adequate dimensions as supplied by manufacturers for use with a specific type and size of cable, wrapped around each jointed conductor;

or

(*c*) Factory impregnated cotton tape or paper-cotton tape wrapped around each jointed conductor and surrounded by a tube of paper or paper-mica composition.

Binders and separators for 3-core unscreened cable joints

329. In the case of 3-core cables the three jointed cores should be bound together by factory impregnated cotton tape or paper binders, and separators of factory impregnated paper or other suitable material may be inserted between the cores. A typical joint of this type is shown in Figure 26.

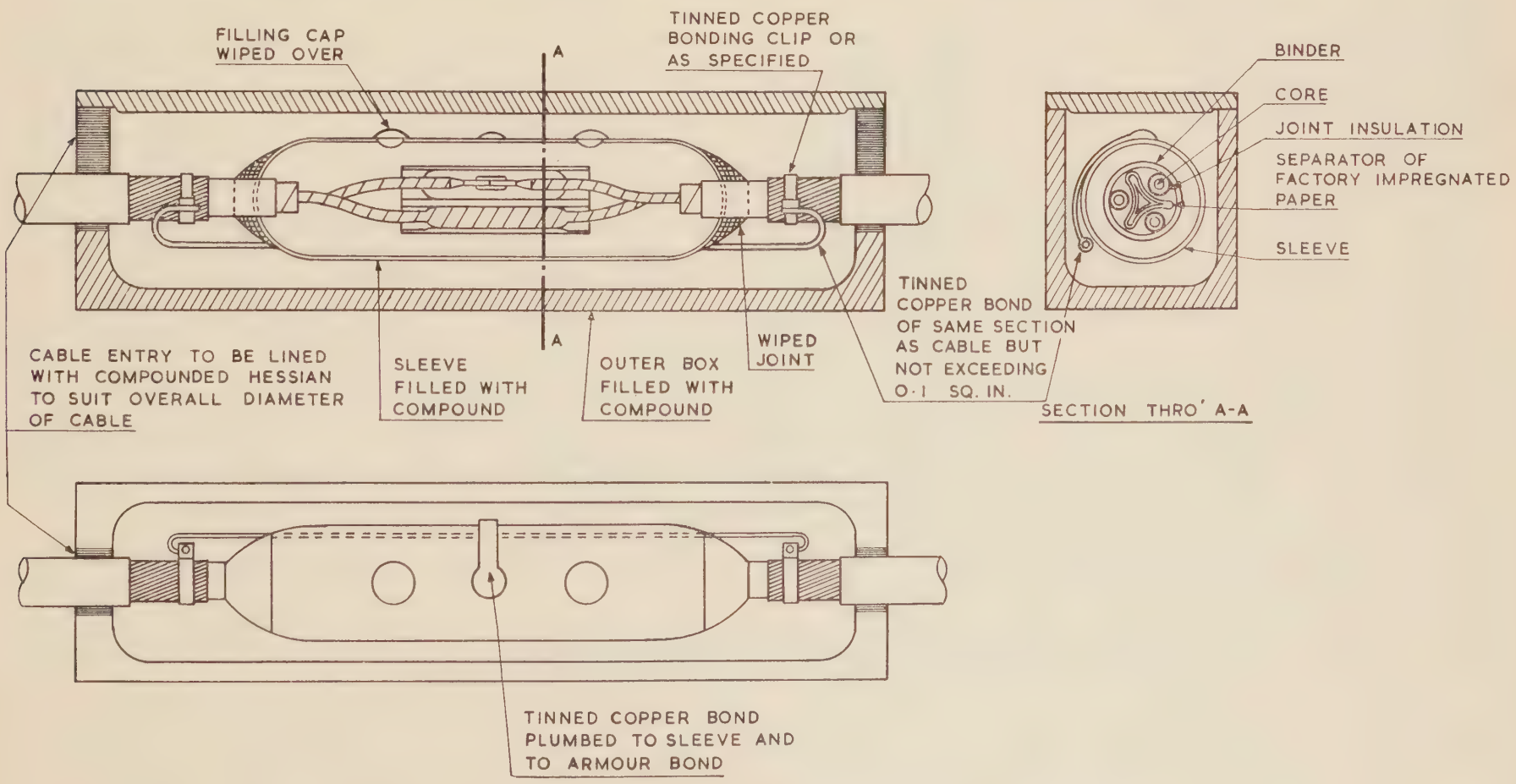

FILLING CAP WIPED OVER
TINNED COPPER BONDING CLIP OR AS SPECIFIED
A
A
BINDER
CORE
JOINT INSULATION
SEPARATOR OF FACTORY IMPREGNATED PAPER
SLEEVE
TINNED COPPER BOND OF SAME SECTION AS CABLE BUT NOT EXCEEDING 0·1 SQ. IN.
CABLE ENTRY TO BE LINED WITH COMPOUNDED HESSIAN TO SUIT OVERALL DIAMETER OF CABLE
SLEEVE FILLED WITH COMPOUND
OUTER BOX FILLED WITH COMPOUND
WIPED JOINT
SECTION THRO' A-A
TINNED COPPER BOND PLUMBED TO SLEEVE AND TO ARMOUR BOND

Figure 26. Typical lead sleeve joint for 11 kV. belted cable with concrete protection box.

Method of joint protection

330. To ensure exclusion of moisture, the insulated joints should be housed in a compound-filled lead or tinned copper receptacle, plumbed to the sheath of the cable. As protection against mechanical damage the receptacle should be provided with an outer protective protective box filled with a suitable compound.

Plumbing metal for lead sheaths

331. The solder to be used for plumbing the lead sleeve or lead or copper box to the lead sheath of the cable should be Grade "D" complying with the requirements of B.S.219.

Plumbing of aluminium sheaths

332. The methods and materials used for plumbing the sleeve or box to the aluminium sheath should be in accordance with the manufacturer's instructions.

Lead sleeves for straight through joints

333. The lead sleeves for straight through joints should consist of solid drawn seamless lead tube made by the extrusion process and should comply with the minimum dimensions given in Figure 27.

Filling holes

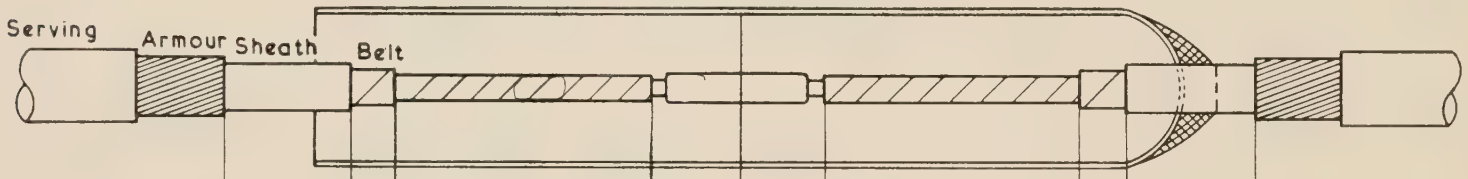
334. Unless otherwise specified, each lead sleeve or lead or copper box should be provided with two "bossed up" filling holes, sufficiently large in diameter to ensure easy filling of the joint. Caps should be supplied for plumbing over these holes after filling the joint with compound.

Filling compound for lead sleeves and lead or copper boxes

335. Lead sleeves and lead or copper boxes should be filled after jointing with compound complying with B.S.1858, preferably Class II having a minimum penetration of 60, or other approved compound.

General requirements for outer protection boxes

336. Where required, outer protection boxes should be of cast iron, or reinforced concrete. The diameter of the cable entries should be greater than the overall diameter of the largest size of cable included in the range for a particular size of protection box, and the intervening space between the circumference of the cable and the interiors of the cable entries caulked with tarred jute, compounded hessian tape, or other suitable waterproof packing.



NORMAL JOINTS PROTECTION BOX TYPE NO. SEE FIG. 28.	CABLE SIZE SQ. IN.				LEAD SLEEVE DIM. NORMAL JOINTS						LEAD SLEEVE DIM. CROSSED CORE JOINTS						CROSSED CORE JOINTS PROTECTION BOX TYPE NO. SEE FIG. 28.
					JOINT NO.	INT. DIA. IN.	LENGTH BEFORE DRESSING DOWN	NOMINAL THICKNESS IN.			JOINT NO.	INT. DIA. IN.	LENGTH BEFORE DRESSING DOWN	NOMINAL THICKNESS IN.			
S.T.2.	0.0225		3	1	2	$2\frac{3}{4}$	$15\frac{1}{2}$"	0.09	$\frac{3}{4}$	$\frac{3}{4}$	4	$3\frac{1}{4}$	18"	0.09		3	S.T. 2.
S.T.2.	0.04		3	1	2	$2\frac{3}{4}$	$15\frac{1}{2}$"	0.09	$\frac{3}{4}$	$\frac{3}{4}$	4	$3\frac{1}{4}$	18"	0.09		3	S.T. 2.
S.T.2.	0.06		3	1	3	3	16"	0.09	$\frac{7}{8}$	$\frac{7}{8}$	5	$3\frac{1}{2}$	20"	0.09		3	S.T. 3.
S.T.2.	0.10		3	1	4	$3\frac{1}{4}$	18"	0.09	1	1	6	$3\frac{3}{4}$	$21\frac{1}{2}$"	0.09		3	S.T. 3.
S.T.3.	0.15		3	1	5	$3\frac{1}{2}$	20"	0.09	$1\frac{1}{4}$	$1\frac{1}{4}$	7	4	$22\frac{1}{2}$"	0.09		3	S.T. 4.
S.T.3.	0.20		3	1	6	$3\frac{3}{4}$	$21\frac{1}{2}$"	0.09	$1\frac{1}{4}$	$1\frac{1}{4}$	8	$4\frac{1}{4}$	$23\frac{1}{2}$"	0.12		3	S.T. 4.
S.T.4.	0.30		3	1	7	4	$22\frac{1}{2}$"	0.09	$1\frac{1}{2}$	$1\frac{1}{2}$	10	$4\frac{3}{4}$	$26\frac{1}{2}$"	0.12		3	S.T. 6.

NOTE: THIS SKETCH FOR CLARITY DEPICTS A SINGLE CORE CABLE BUT THE DIMENSIONS APPLY EQUALLY TO MULTICORE CABLES.

Figure 27. Dimensions for high voltage 11 kV straight through cable joints.

Cast iron protection boxes

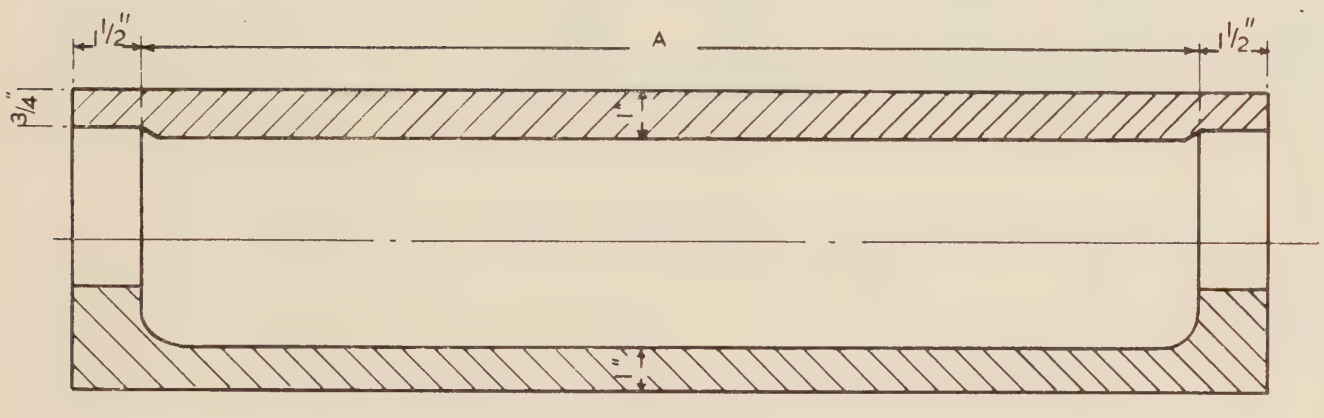
337. Cast iron protection boxes should be of close grained iron, free from defects and sized to provide not less than $\frac{3}{8}$″ of compound filling space around the enclosed sleeve, and the internal length should be at least 4″ greater than the overall length of the sleeve. Cast iron protection boxes should be divided along the centre line and provided with deep tongue and groove or other approved joints. The clamping bolts for securing the two half-boxes should be so arranged that they can be readily removed after slackening. Suitable armour clamps should be provided on the box extremities for ensuring the efficient mechanical and electrical bonding of the armour across the joint. The box should be separately bonded to the cable sheath. The compound filling holes should each be not less than 3 sq. in. in area and should be provided with suitable cover plates. As a protection against rusting cast iron boxes should be given two coats of bituminous paint.

Non-metallic protection boxes

338. Reinforced concrete protection boxes should be generally in accordance with Figures 26 and 28. Efficient means for bonding the armour across the joint and to the cable sheath should be provided. Two methods of bonding steel wire armoured cables are shown in Figure 29.

Filling compound for outer protection box

339. The outer protection box should be filled with suitable compound.



CABLE ENTRY TO BE LINED WITH COMPOUNDED HESSIAN TAPE OR JUTE TO SUIT DIAMETER OF CABLE

BOX TYPE	LEAD SLEEVE Approx. DIA. IN.	Approx. DIA. IN.	A	B	C	D
S.T.1	2	13	18 ″	3 1/2 ″	4 ″	1 1/2″
S.T.2	3	18	24 ″	4 1/2 ″	5 ″	2 1/2 ″
S.T.3	3 1/2	22	28 ″	5 ″	5 ″	3 ″
S.T.4	4	23	31 ″	5 1/2 ″	5 1/2 ″	3 1/2 ″
S.T.5	5	25	34 ″	6 1/2 ″	6 1/2″	3 1/2 ″

Figure 28. Typical concrete protection box for 11 kV straight through joints showing minimum dimensions and general arrangement.

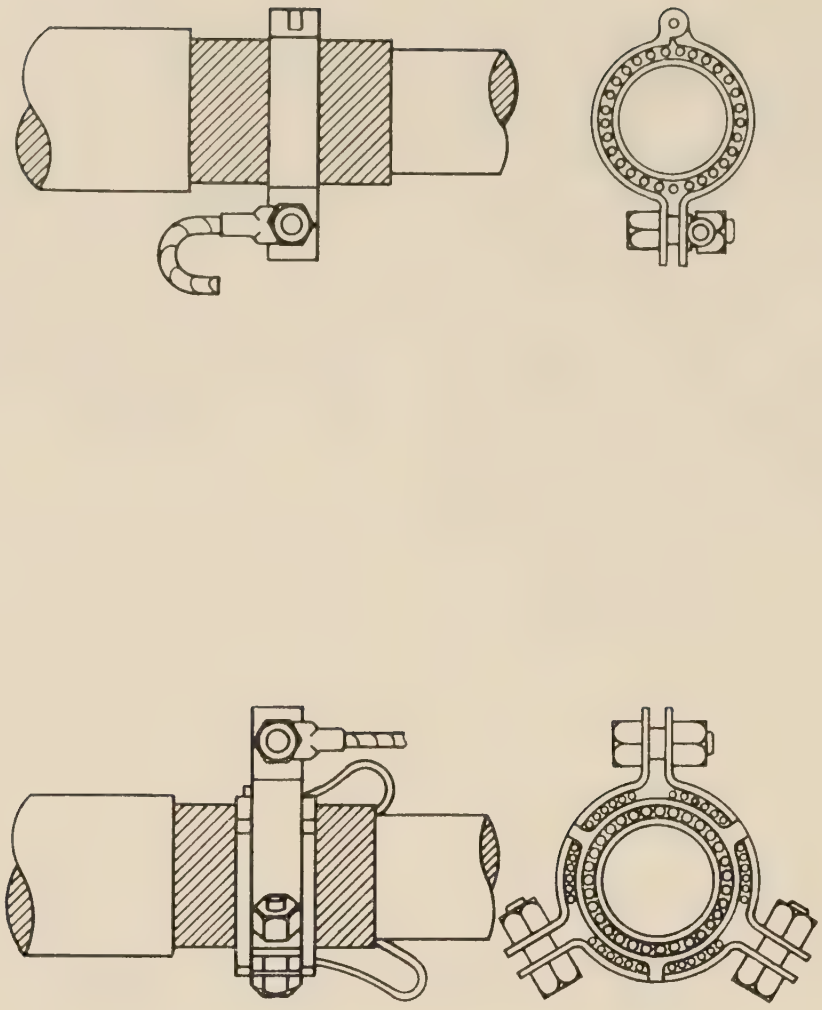


Figure 29. Methods of bonding wire armour across joints encased in non-metallic protection boxes.

References

BRITISH STANDARDS INSTITUTION

B.S.31: Steel conduits and fittings for electrical wiring.
B.S.37: Electricity meters.
B.S.77: Voltages for a.c. transmission and distribution systems.
B.S.81: Instrument transformers.
B.S.88: Electric fuses for circuits of voltage ratings up to 660 V.
B.S.89: Electrical indicating instruments.
B.S.91: Electrical cable soldering sockets.
B.S.108: Graphical symbols for general electrical purposes.
B.S.116: Oil circuit-breakers for alternating current systems.
B.S.142: Electrical protective relays.
B.S.148: Insulating oil for transformers and switchgear.
B.S.159: Busbars and busbar connections.
B.S.171: Power transformers.
B.S.219: Soft solders
B.S.341: Valve fittings for compressed gas cylinders.
B.S.401: Steel cylinders for the storage and transport of 'liquefiable' gases.
B.S.480: Impregnated paper-insulated cables for electricity supply.
B.S.601: Steel sheets for magnetic circuits of power electrical apparatus.
B.S.690: Asbestos—cement slates and sheets.

B.S.697: Rubber gloves for electrical purposes.

B.S.801: Lead and lead alloy sheaths of electric cable.

B.S.861: Air Break Switches (including isolating switches, totally enclosed and flame-proof types), for voltages not exceeding 660V.

B.S.862: Air break circuit breakers for voltages not exceeding 660V.

B.S.921: Rubber mats for electrical purposes.

B.S.1387: Steel tubes and tubulars suitable for screwing to B.S.21 pipe threads.

B.S.1650: Capacitors for connection to power-frequency systems.

B.S.1710: Identification of pipe lines.

B.S.1858: Bitumen-base filling compounds for electrical purposes.

B.S.1991: Letter symbols, signs and abbreviations.

B.S.2046: Protective transformers.

B.S.2510: Composite units of switches and fuses for use with industrial systems and domestic circuits.

B.S.2562: Cable sealing boxes for oil-immersed transformers.

B.S.2631: Oil switches for alternating current systems.

B.S.2692: Fuses for alternating-current circuits above 660V.

B.S.2746: P.V.C. insulation and sheath of electric cables.

B.S.2791: Aluminium conductors in insulated cables.

B.S.2898: Wrought aluminium and aluminium alloys for electrical purposes.

B.S.2899: Rubber insulation and sheath of electric cables.

Part 1. Natural rubber, etc.

Part 2. Silicone rubber insulation

Part 3. Butyl rubber insulation and sheath.

B.S.3185: Heavy-duty composite units of air-break switches and fuses for voltages not exceeding 660V.

B.S.3207: Mineral-insulated cables.

Part 1 1960 copper-sheathed cables with copper conductors.

B.S.3258: Silicone rubber insulated cables and flexible cords.

B.S.3346: Armoured p.v.c. insulated cables.

B.S.3360: Copper conductors in insulated cables and cords.

B.S.3387 Butyl-rubber insulated cables and cords with heat resisting fibre layer.

Codes of Practice.

C.P.1010: Guide to loading of oil-immersed transformers to B.S.171.

C.P.321: Electrical installations.

C.P.321.101 Electric wiring system.

C.P.321.102 Installation and maintenance of electrical machines, transformers, rectifiers, capacitors and associated equipment.

British Electricity Boards.

BEBS—T1 Specification for transformers from 5 kVA to 1000 kVA for use on standard 415V and 240V systems.

BEBS—S2 Specification for standard distribution switchgear rating 150 MVA at 6·6 kV and at 11 kV.

Addendum to BEBS—S2 Standard distribution switchgear rating 250 MVA at 11 kV.

Explanatory memorandum on Specification S2.

Index (*paragraph numbers*)

Abbreviations used, 3

Access to sub-stations, 236

Accommodation schedule, 10

Aluminium
- busbars, for medium voltage (Appendix IV)
- cable sheaths (see also cables), 139, 167-170
- conductors, 137, 167-170
- joints in, 306-308, 327

British standards, compliance with, 18

Builders' work, 13

Busbar
- capacity, 16, 23
- chamber, 199
- conductors and connections, 200-207
- sizes and ratings (Appendix IV)
- trunking systems, 155-166
  - expansion joints in, 163

Cable(s)
- aluminium conductors in, 137
  - sheathed, 139
- armouring, 99, 101, 142, 143, 152
- bending radius, 152
- conduits, 295
- cover tiles, 293
- depth of laying, 299
- ducts, 250-252
- high voltage, 90-101
  - depth of laying, 299
- in conduit and trunking, 177-182
- joints, high voltage, 323-339
  - binders and separators for, 329
  - cast iron protection boxes for, 337
  - conductors of equal size with, 325
  - filling compound for, 335, 339
  - filling holes in, 334
  - insulation of, 328
  - lead sleeves for, 333
  - non-metallic protection boxes for, 338
  - plumbing metal for, 331
  - plumbing of aluminium sheaths in, 332
  - protection of, 330
  - protection boxes for, 336-338
  - soldering aluminium conductors in, 327
  - soldering copper conductors in, 326

Cables (continued)
- joints, medium voltage, 140, 141, 301-322
  - aluminium joints in, 306
  - compression joints in, 308
  - filling compound for, 317, 322
  - filling holes in, 315
  - insulation of, 312
  - lead sleeves in, 313
  - plumbing metal used in, 316
  - protection boxes for, 318-321
  - solder used in, 311
  - soldered aluminium conductors in, 306, 307
  - sweated conductors in, 305
  - tee boxes for, 314
- markers, 293
- medium voltage, types of, for external feeders, 135-152
- mineral insulated, 150, 151, 167-176
- paper insulated, for medium voltage, 135, 136
  - for high voltage, 91, 93, 94, 96, 97, 100
- p.v.c. insulated, 92, 146-149
- plan, 300
- external runs, 293-299
- sheathing aluminium 139
  - lead, 138
- serving, 144, 145, 153
- terminations, 309
- trays, 175

Capacitors, power factor correction for, 38, 39

Circuit(s)
- breakers, high voltage, 60-65
- breaker, operating mechanism, 73-78
  - trip coil supply, 79-81
- lift, 20, 134
- protection of, 17, 60-71
- ring, high voltage, 49, 50
  - medium voltage, 128, 129
- segregation of, 20
- x-ray, 130-133

Conduit(s) and trunking, cables in, 177-182
- for external cable runs, 294-298

Copper
- busbars for medium voltage (see also busbars) (Appendix IV)
- conductors, in m.v. cable joints, 305, 308
  - in h.v. cable joint, 326

Cost comparison, high and medium voltage, fig. 3

Crawlways (see also ducts), 292

Current transformers, 82, 83

Design
of distribution system, 6-10, 16, 23
of installation for growth and change, 14, 15
procedures, 6-13
stages in, 5

Discrimination, 17, 63, 66, 67, 198

Distribution feeders, external, 135-152
internal, 153-190
high voltage, 45-52
main circuits, diversity, 26
medium voltage, 124-127
sub-centres, 16, 17, 212-214
voltage, choice of, 43, 44

Diversity factor(s), 26, 27, 131, 133
x-ray circuits, 133

Drawings record, 226, 227

Duct(s)
crawlways and external cable runs, 287-300 (fig. 22)
in sub-stations, 250-252
and trunking systems, 183, 184

Earthing, 218-225 (fig. 16)

Electric, shock, treatment notice, 286

Electrical loads, typical for existing hospitals, 21, 22
estimated for new hospitals, 23

Electricity supply
discussion with authority, 7
standby, 28-33

Feeder
circuits, protection of, 68-71
external, medium voltage, 135-152
internal, medium voltage, 153-190
out to other users, 9
pillars, 215-217

Fire
extinguishing apparatus, 263-268
protection in sub-stations, 253-254

Fuses, 197-198
discrimination with, 198
standardisation of, 18

Handing-over procedure, 228-233

Heating
in sub-stations, 259
in switchrooms (medium voltage), 279
space, 19
water, 19

High Voltage
cables, 45, 90-101
cables, depth of laying, 299
cable joints (see also Cable joints), 323-339
circuit breakers, 60-65
distribution, 45-52
distribution, preferred voltages, 44
sub-stations (see also Sub-stations), 234-271
supply, 9, 41, 42
switchgear, 45-46, 53-89
isolation of, 31

Installation
capital costs and losses, 43
design allowance for future, 10, 14, 15

Insulation
cable joints medium voltage, 312
high voltage, 328

Interlocks, normal and standby supplies, 32

Insulators, busbar, 201, 202

Joints (see Cable joints)

Kitchens, 22

Laboratories, 22

Laundries, 22

Lift(s)
circuits, 20, 134
shafts, services in, 290

Lighting
diversity factors for, 26, 27
standards, upgrading of, 22
sub-stations, 260
switchrooms, 281

Load(s)
centres of gravity, 12
electrical, existing hospitals, 22
new hospitals, 23
non-typical, 25
pattern, 16, 19

Maintenance, 18

Main, rising, duct, (figs. 14 and 15)

Maximum demand
charge, 36, 39
estimated, 6, 21-25
increase in, 21, 22

Medium Voltage
cables, 45, 135-190
cable joints (see also Cable joints), 301-322
distribution feeders, 43
external, 135-152
internal, 153-190
switchboards, 191-217
switchgear, 194-196
switchrooms (see also Switchrooms), 272-286 (fig. 21)

Meters, 208-210

Oil
retaining in sub-stations, 247-249
switches, high voltage, 85-88
switch-fuses, high voltage, 89

Power factor correction, 34-39

Protection
of feeder circuits, 68-71
of transformer circuits, 66, 67

Radial distribution, 51

Record drawings, 226, 227

Ring circuits, 49, 50, (figs. 4, 6 and 7), 128, 129

Segregation of circuits, 20

Service ducts, 11

Sketch plan, 11

Socket outlets
in sub-stations, 262
in switchrooms, 282

Standby
electricity supplies, 28-33
generator, 31

Sub-distribution centres, 11, 16, 17, 212-214 (figs. 14 and 15)

Sub-station(s)
access to, 236
construction of, 242-246
fire extinguishing apparatus, 263-268
fire protection, 253
heating, 259
high voltage, 9, 234-271
layout, 237
lighting, 260-261
outdoor, 122
packaged, 120, 121
siting of, 7
socket outlets in, 262
ventilation of, 256-258
warning notices in, 269-271

Supply
authority, discussions with, 7
integrated medium voltage, 9
interruption of, 17
mains, routing of, 7
provision of, 7
standby electricity, 28-33
voltage, choice of, 40-42

Switch(es)
fuse, high voltage, oil, 89
high voltage, oil, 85-88
trip, for circuit breakers, 255

Switching for standby supplies, 29

Switchboard(s)
framing, 211
medium voltage, 191-217

Switchgear
high voltage, 45-47, 53-89
marking of, 283
medium voltage, 194-196
standardisation of, 18

Switchroom(s)
medium voltage, 272-286
floor of, 274
heating in, 279
lay-out, 273
lighting of, 281
rubber mats in, 278
separation of supplies in, 277
socket outlets in, 282
spares and tools, etc. in, 285
trenches in, 276
ventilation of, 280
walls of, 275
wiring diagrams in, 284

Symbols used in wiring diagrams, (fig. 1)

Tariff
charges, 7
off-peak, 19
power factor penalty, 35

Transformer(s)
approx. cost of, (fig. 12)
current, 82, 83
high voltage, 102-123

Transformers (continued)
number of, 104-107
oil retaining arrangement, 247, 248
protection, 66, 67
size, 108, 109
types of, 102, 103, 110-119

Trip coil supply for circuit breakers, 79-81.

Trunking
cable, 185-190
and duct systems, 183, 184

Ventilation
higher standards of, 22
sub-stations, 256-258
m.v. switchrooms, 280

Voltage
distribution, choice of, 43, 44
drop, 43, 156
regulation, 9
of supply, choice of, 40-42

X-Ray circuits, 20, 130-133

MINISTRY OF HEALTH

HOSPITAL TECHNICAL MEMORANDA

The following titles in this series have been issued:

		PRICE NET s.	d.
1.	Anti-static precautions: rubber, plastics and fabrics	1	0 (*post* 3*d.*)
2.	Anti-static precautions: flooring in anaesthetising areas	1	3 (*post* 3*d.*)
3.	Fire precautions: fish fryers	1	0 (*post* 3*d.*)
4.	Colour code of flexible cables and cords		6 (*post* 3*d.*)
5.	Steam boiler plant instrumentation	1	6 (*post* 3*d.*)
6.	Protection of condensate systems: filming amines ...		6 (*post* 3*d.*)
9.	Pneumatic tube communications systems	1	6 (*post* 3*d.*)

Printed in England for Her Majesty's Stationery Office by McCorquodale Printers (Crewe) Ltd.
26/6/63). 90212. Wt. 3611–9528. K.48. 18/11/63. 401

© *Crown copyright* 1963

Published by
HER MAJESTY'S STATIONERY OFFICE

To be purchased from
York House, Kingsway, London w.c.2
423 Oxford Street, London w.1
13A Castle Street, Edinburgh 2
109 St. Mary Street, Cardiff
39 King Street, Manchester 2
50 Fairfax Street, Bristol 1
35 Smallbrook, Ringway, Birmingham 5
80 Chichester Street, Belfast 1
or through any bookseller

S.O. Code No. 32-509-7.